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PROCEEDINGS OF THE WORLD SYMPOSIUM ON WARM-WATER POND FISH CULTURE

ACTES DU SYMPOSIUM MONDIAL SUR LA PISCICULTURE EN ÉTANG A TEMPÉRATURE ÉLEVÉE

ACTAS DEL SIMPOSIO MUNDIAL SOBRE PISCICULTURA EN ESTANQUES DE AGUA TEMPLADA

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PROCEEDINGS OF THE FAO WORLD SYMPOSIUM ON WARM-WATER POND FISH CULTURE

ACTES DU SYMPOSIUM MONDIAL ORGANISE PAR LA FAO SUR LA PISCICULTURE EN ETANG A TEMPERATURE ELEVEE

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Rome, Italy, 18-25 May 1966
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VOLUME III - REVIEW AND EXPERIENCE PAPERS OF MEETINGS II AND III

VOLUME III - ETUDES SPECIALISEES ET COMPTES RENDUS D'EXPERIENCES DES REUNIONS II ET III

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PREPARATION OF THIS VOLUME

This is the third volume of the Proceedings of the FAO World Symposium on Warm-water Pond Fish Culture and contains the review and experience papers contributed to Meeting II (on Fertilization and Role of Soil in Fish Pond Productivity) and Meeting III (on Feeds and Feeding).

The first and second volumes contain the report of the Symposium and the regional and country reports, respectively. The subsequent volumes will contain the review, experience and working papers of Meetings IV to IX of the Symposium.

The views expressed in the contributions are those of the authors and not necessarily of the Food and Agriculture Organization of the United Nations.

Dr. (Mrs.) Rosemary McConnell and Dr. Homer Swingle assisted in the editing of some of the contributions.

PREPARATION DU PRESENT VOLUME

Le présent volume est le troisième des Actes du Symposium mondial organisé par la FAO sur la pisciculture en étang à température élevée. Il contient les études spécialisées et les comptes rendus d'expériences présentés à la réunion II (Fertilisation des étangs et rôle du sol dans la productivité) et à la réunion III (Aliments pour poissons et alimentation artificielle).

Les premier et deuxième volumes renferment le rapport du Symposium et les rapports régionaux et nationaux, respectivement. Les volumes suivants contiendront les études spécialisées, les comptes rendus d'expériences et les documents de travail relatifs aux réunions IV à IX du Symposium.

Les opinions exprimées dans les communications sont celles des auteurs, et ne représentent pas nécessairement celles de l'Organisation des Nations Unies pour l'alimentation et l'agriculture.

Mme. Rosemary McConnell et M. Homer Swingle ont collaboré à la mise au point de certaines des communications.

PREPARACION DE ESTE VOLUMEN

Este es el tercer volumen de las actas del Simposio Mundial de la FAO sobre Piscicultura en Estanques de Agua Templada y contiene los documentos de información y experiencias que fueron presentados a la Reunión II (La fertilización y la función del suelo en la productividad de la estanicultura) y a la Reunión III (Tipos de alimentos y métodos de alimentación.

El primero y el segundo volumen contienen el Informe sobre el Simposio y los informes regionales y nacionales, respectivamente. En los volúmenes sucesivos se incluirán los documentos de información, experiencias y trabajos de las Reuniones IV a IX del Simposio.

Las opiniones expuestas en los documentos presentados son las de los autores de los mismos y no reflejan necesariamente las de la Organización de las Naciones Unidas para la Agricultura y la Alimentación.

La doctora Rosemary McConnell y el doctor Homer Swingle colaboraron en la redacción de algunos de estos documentos.

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SOME LIMITING FACTORS AFFECTING THE DOSE OF FERTILIZERS ADDED TO FISH PONDS, WITH SPECIAL REFERENCE TO THE NEAR EAST

by

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Abstract

Three groups of limiting factors affecting the fertilizer dose - chemical, biological and economic - are discussed.

The chemical equilibrium in pond water is relatively stable. The added mineral nutrients upset this stability and are, therefore, withdrawn from the water. The higher the concentration of the added nutrient in the water, the higher the rate of its withdrawal. This limits the dose of fertilizers, as larger amounts of fertilizer do not result in higher concentration of the added nutrient.

Various factors may limit the growth of fish or their food chain biologically. Higher phytoplankton production does not result in higher fish yields in the presence of any of the limiting factors. In such cases fertilizer dose may be reduced.

The economic limit of fertilization is reached when the value of the increased amount of fish yield due to fertilization is equal to the value of the fertilizer added to obtain it.

II/R-1

CERTAINS FACTEURS LIMITATIFS INFLUANT SUR LA DOSE D'ENGRAIS APPLICABLES AUX ETANGS DE PISCICULTURE, NOTAMMENT AU MOYEN-ORIENT

Résumé

Trois groupes de facteurs limitatifs influant sur la dose d'engrais sont examinés: les facteurs chimique, les facteurs biologiques et les facteurs économiques.

L'équilibre chimique de l'eau est relativement stable en étang. Cet équilibre étant rompu par l'apport d'éléments nutritifs exogènes, ces éléments tendent donc à être éliminés de l'eau. Plus la concentration des éléments ajoutés est élevée dans l'eau, plus le rythme d'élimination est rapide. Ce phénomène limite la dose utile d'engrais puisqu'un apport plus important n'entraîne pas une teneur plus élevée en éléments nutritifs.

Du point de vue biologique, divers facteurs peuvent limiter la croissance des poissons ou leur chaîne alimentaire. Une production plus forte de phytoplancton n'entraîne pas une productivité plus élevée du poisson en présence de l'un quelconque de ces facteurs limitatifs. Dans de tels cas, la dose d'engrais peut être réduite.

La limite économique de fertilisation est atteinte lorsque la valeur de la production supplémentaire de poisson due à l'utilisation d'engrais devient égale à la valeur des engrais utilisés pour obtenir ce surcroît de production.

ALGUNOS FACTORES LIMITANTES QUE INFLUYEN EN LA DOSIS DE FERTILIZANTES ADICIONADOS A LOS ESTANQUES PISCICOLAS EN LO QUE SE REFIERE ESPECIALMENTE AL MEDIO ORIENTE

Extracto

Se examinan tres grupos de factores limitantes que influyen en las dosis de fertilizantes: químicos, biológicos y económicos.

El equilibrio químico en las aguas de los estanques es relativamente estable. Los minerales nutrientes añadidos alteran esta estabilidad y, por consiguiente, se eliminan del agua. Guanto mayor es la concetración del nutriente adicionado al agua, tanto más elevada es la tasa de su eliminación. Esto limita la dosis de los fertilizantes, ya que al aumentar las cantidades de éstos no da por resultado una mayor concentración del nutriente añadido.

Varios factores pueden limitar biológicamente el crecimiento de los peces o su cadena alimentaria. Una mayor producción de fitoplancton no da por resultado mayores rendimientos de peces en presencia de cualquiera de los factores limitantes. En tales casos, debe reducirse la dosis de fertilizante.

El límite económico de la fertilización se alcanza cuando el valor del aumento de rendimiento de peces, debido a la fertilización, iguala al valor del fertilizante añadido para obtenerla.

1 INTRODUCTION

Experiments carried out in various parts of the world since the beginning of the century have proved that fertilization of fish ponds can increase fish yields considerably. Thus fertilization is considered one of the more important means of intensifying fish culture. No wonder, then that in the intensive fish culture in Israel, fertilization has become a common practice in commercial fish farms. Research and empirical experience have made it possible to establish some standards in fish pond fertilization in Israel, yet a great deal still remains to be determined. A particular problem in this regard relates to dose and frequency of fertilization. Some of the factors affecting fertilization dosage under Near Eastern conditions are discussed below.

Three main groups of factors limit the fertilizer dose - chemical, biological and economic.

2 CHEMICAL FACTORS

The water in fish ponds is a complicated chemical system of equilibria in which the bottom soil takes an active part. These equilibria govern the cycles of the elements in the pond and their concentration in the water. There is a close interaction between these chemical equilibria and various physical, biological, and edaphic factors such as temperature, photosynthesis, bottom soil composition, etc. These factors affect, and are at the same time affected by changes in the chemical equilibria and the cycle of events in the pond.

Some of the factors affecting the equilibria such as temperature, oxygen tension, etc. may vary to some extent, but these variations usually remain within fixed limits which are determined by local conditions of climate, geology, and soil composition. As a result, there is a certain stability in the chemical equilibria in the water and the extent of variation in the concentration of the elements in the water of the pond is limited.

The adding of mineral nutrients in fertilization of the pond upsets the chemical equilibria. The equilibria, however, tend to re-establish themselves and the added elements are withdrawn from the water by various chemical and physico-chemical reactions.

In Near Eastern conditions, the phosphorous, which is the most important fertilizer added to the pond, is adsorbed to bottom soil colloids (Hepher, 1958) or precipitated as calcium phosphate (Matida, 1956; Hepher, 1958). In the temperate region similar reactions bring about the same result. In this case the reacting elements are usually iron and aluminium, precipitating the phosphate as iron and aluminium phosphates, or adsorbing it on the ferric hydroxide gel of the bottom soil (Ohle, 1937; Einsele, 1938).

The reactions causing the disappearance of nitrogen from the water have been studied to a lesser extent. It seems that in alkaline water some of the nitrogen is converted to gaseous ammonia which escapes from the water into the air. Another part of the added nitrogen is probably adsorbed by cation exchange reactions to soil colloids (Mandal, 1962), and then leached away.

All these reactions cause a rapid disappearance of the added nutrients from the water. Moreover, the rate of disappearance is dependent on the concentration of the nutrient in the water. The higher the concentration, the quicker the disappearance of the nutrient. This, of course, limits the amount of fertilizer that can be added to the pond. Past a certain point the rate of disappearance is so high that actually no further increase in the concentration of the nutrient in the water can be achieved. This was clearly shown in the experiments of Rashkes (Sarig) (1949) and Reich (1950), where even after adding large doses of phosphate fertilizer, the recovery was seldom over 0.5 mg/l P - only a fraction of the phosphorus added. It has already been shown theoretically (Hepher, 1958) that under Israeli conditions, the fraction of the phosphate added above this level is precipitated as calcium phosphate. Similar results have been observed when large amounts of nitrogen were added to the water. The concentration seldom exceeded 2.0 mg/l N.

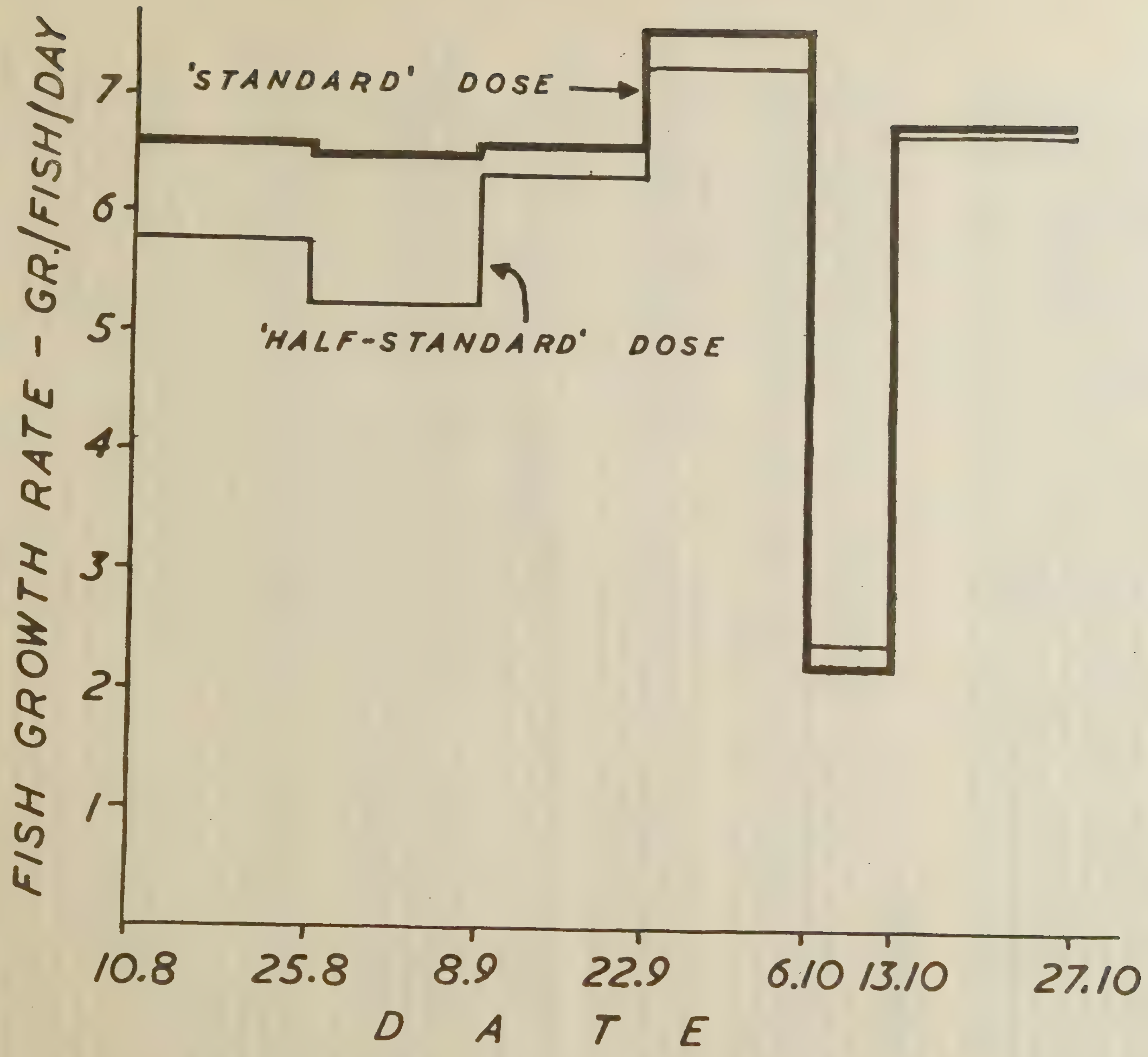

Fig. 1. The average daily growth rate of fish in ponds receiving different fertilization treatments (for actual amounts see text).

It is clear then, that chemical factors limit the dose of fertilizer, as there is no point in adding nutrients which will be lost immediately.

3 BIOLOGICAL FACTORS

No doubt, part of the nutrients added as fertilizer is taken up by the phytoplankton and serves the initial purpose of increasing the pond's productivity. The phytoplankton is the first and basic link in the food chain of the fish. Increasing the phytoplankton productivity activates the whole food chain, with the resulting increase in fish yields. The food chain and the growth of the fish are affected, however, by a number of factors, of which phytoplankton productivity is only one. Factors, such as temperature, pH, etc. may affect any link in the food chain or the fish itself. If any one of these factors becomes a limiting factor, increasing phytoplankton production would not result in increased fish yield. In such cases the dose of fertilizer may be smaller.

An example of such a case may be seen in the results of a fertilization experiment given in Fig. 1. In this experiment, which began in August 1963 and continued through 27 October, 11 ponds were fertilized every two weeks with 60 kg/ha superphosphate and 60 kg/ha ammonium sulphate ('Standard fertilization'), and nine ponds were fertilized with only 30 kg/ha superphosphate and 30 kg/ha of ammonium sulphate. In summer there was a noticeable difference in the growth of the fish in the two treatments, the former being higher. As temperature dropped in autumn this difference disappeared.

Limiting factors other than nutrient elements added by fertilization may affect phytoplankton production itself. Such a case is described by Hepher (1962) where light became a limiting factor. Fertilization of fish ponds with large amounts of fertilizers increased production in the upper layers of the water where favourable light conditions exist, but decreased production in the lower layers, where shading by the plankton caused a decrease in light penetration. The effect of a large dose of fertilizer may thus cause a lowering of production per unit area.

4 ECONOMIC FACTORS

The effect of fertilizers on fish yield, like the effect of any other growth factor, is governed by the law of diminishing returns. In our case, this means that each successive portion of fertilizer causes a smaller return in yield, until the optimum point is reached where there is no further increase of yield with the increase in fertilizer.

From an economic point of view the optimum dose of fertilizer is reached before this levelling off of the yield curve occurs. It is reached when the price of the 'last' portion of fertilizer equals the value of the increase in fish yield received in return. The following may illustrate this point.

Experiments at Dor have shown that fertilization with a 'standard' dose of fertilizers increased the fish yield by 88 percent in ponds where fish were fed (Hepher, 1962a). Considering the average yield of 2,100 kg/ha in Israeli commercial ponds, this gain is equal to about 980 kg/ha.

Another experiment (Hepher and Chervinski, 1965) showed that the yield in ponds fertilized with half the 'standard' dose (30 kg/ha of each of the fertilizers mentioned every two weeks, or 425 kg/ha per year) was about 6.1 percent lower than in ponds receiving the full 'standard' dose. (And not half the gain, or 44 percent, as could be expected if a linear relationship had existed between fertilizer and yield). This decrease is equal to about 128 kg/ha of fish, the value of which, in Israel, is three times the value of the fertilizers added to achieve it. One can see that in this case fertilization is still economical. By further experiments (which unfortunately were not carried out in this case) the economic limit of the fertilization dose can be found more accurately.

It may be concluded that these three groups of factors, which may differ between localities, determine the dose of fertilizers that should be added to fish ponds. Only by studying the effects of these factors on fertilization and on fish yield can the optimum fertilizer dose be found.

5 REFERENCES

Einsele, W., Uber chemische und kolloidchemische Vorgänge in Eisen-phosphatsystemen unter
1938 limnochemischen und limnogeologischen Gesichtspunkten. Arch.Hydrobiol., 33:361-87

Hepher, B., On the dynamics of phosphorus added to fish ponds in Israel. Limnol.Oceanogr.,
1958 3(1):84-100

___________, Primary production in fish ponds and its application to fertilization experi-
1962 ments. Limnol.Oceanogr., 7(2):131-6

___________, Ten years of research in fish pond fertilization in Israel. 1. The effect
1962a of fertilization on fish yields. Bamidgeh, 14(2):29-38

Hepher, B. and J. Chervinski, Studies on carp nutrition - the influence of protein-rich
1965 diets on growth. Bamidgeh, 17(2):31-46

Mandal, L.N., Nitrogenous fertilizers for brackish water fish ponds, - ammonium or nitrate
1962 form? Indian J.Fish.(A), 9(1):123-4

Matida, Y., Study of farm fish culture. 3. Fates of fertilized elements and the relation-
1956 ship between the efficiency of fertilizer and biochemical environment in the pond. Bull.Freshw.Fish.Res.Lab., Tokyo, 6(1):27-39

Ohle, W., Kolloidgele als Nahrstoffregulatoren der Gewässer. Naturwissenschaften, 25:
1937 471-4

Rashkes (Sarig), S., (On the nitrogen and phosphorus regime in the river Asi and the ex-
1949 perimental ponds at Nir David). Alon Lemegadley Dagim, (26/27):1-12; (28): 1-7 (In Hebrew)

Reich, K., (On a small scale experiment for the determination of a fertilization method).
1950 Alon Lemegadley Dagim, (32):1-9 (In Hebrew)

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A REVIEW OF THE METHODS OF FERTILIZING WARM-WATER FISH PONDS IN ASIA AND THE FAR EAST

by

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Abstract

Traditional methods of fish-pond fertilization are reviewed. In China, Hong Kong, Taiwan, Singapore and Malaysia, Chinese carps are raised in conjunction with pigs and ducks. Cut plants and night soil are often added. In India where other carps are cultured, cut plants, oil seed cake and sewage are used as fertilizers. In brackish-water ponds of Taiwan, Philippines and Indonesia, cut weeds, rice bran, seed cake and manure are added as fertilizer and food. Experiments on artificial fertilizers have been carried out in Taiwan, Philippines and India, but have been based on N-K-P mixtures. In Malacca it has been shown that only phosphate fertilizer is needed in ponds, and this method is more economical in labour and costs.

REVUE DES METHODES DE FUMURE PRATIQUEES DANS LES ETANGS PISCICOLES A TEMPERATURE ELEVEE EN ASIE ET EN EXTREME-ORIENT

Résumé

La communication passe en revue les méthodes traditionnelles de fertilisation des étangs de pisciculture. En Chine, à Hong-Kong, à Taïwan, à Singapour et en Malaysie, les carpes chinoises sont élevées en association avec des porcs et des canards. Il n'est pas rare que l'on procède à des apports d'engrais flamand et de plantes coupées. En Inde, où d'autres carpes sont élevées, on se sert, comme engrais, de plantes coupées, de tourteaux d'oléagineux et d'eaux d'égoût. Dans les étangs à eau saumâtre de Taïwan, des Philippines et d'Indonésie, des plantes coupées, du son de riz, des tourteaux et du fumier sont déversés dans l'eau pour servir d'engrais et d'aliments. Des expériences ont été faites à Taïwan, aux Philippines et en Inde avec des engrais artificiels et notamment des mélanges de N-K-P. A Malacca, il a été prouvé que les étangs n'avaient besoin que d'engrais phosphatés et la méthode appliquée s'avère peu onéreuse tant en matière première qu'en main-d'oeuvre.

EXAMEN DE LOS METODOS DE FERTILIZACION DE LOS ESTANQUES PISCICOLAS DE AGUAS CALIDAS EN ASIA Y EL LEJANO ORIENTE

Extracto

Se pasa revista a los métodos tradicionales de fertilización de los estanques piscícolas. En China, Hong-Kong, Taiwan, Singapur y Malasia, se cría la carpa china conjuntamente con los cerdos y los patos. Con frecuencia se adicionan plantas cortadas y residuos fecales. En la India, en donde se cultivan otros tipos de carpa, se utilizan como fertilizantes plantas cortadas, tortas de semillas oleaginosas y aguas cloacales. En los estanques de aguas salobres de Taiwan, Filipinas e Indonesia se añaden como fertilizantes y alimentos plantas cortadas, salvado de arroz, torta de semillas y estiércol. En Taiwan, Filipinas y la India se han llevado a cabo experimentos de fertilizantes artificiales basados en mezclas de N-K-P. En Malaca se ha demostrado que solamente se necesitaban en los estanques abonos fosfatados y que este método es más económico en cuanto a mano de obra y costo.

Fish culture has been practised in many Asian countries for a very long time, in China for over two thousand years. Use is made of materials easily available and so methods may vary from place to place, particular methods sometimes being restricted to particular geographic areas. Migrating populations, especially the Chinese, have taken their methods of fish culture with them, not always to areas most suited to such methods. Underlying most traditional fish culture is the use of organic matter to fertilize the ponds, since it is only in recent years that inorganic fertilizers have become freely available.

1 CHINA

In S. China the culture of carps (mainly *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis* and *Cyprinus carpio*) is often associated with pig rearing, and this is particularly true in Kwangtung province. Pig sties are built on the sides of the ponds and the manure and washings serve to fertilize the water. Night soil is often added and latrines are even built out over the water. In other parts duck rearing is coupled with fish culture, the duck pens being built out over the water surface to give the maximum fertilizing effect. Poultry droppings are often used as well. Where buffaloes and cattle are more plentiful their manure is often used to fertilize ponds, and the byres may be built close to the water. A certain amount of green manuring is practised, but more often cut grass, goatweed and other strong smelling weeds, and aquatic plants may serve directly as food for fish like the grass carp, or for invertebrates which in turn serve as fish food. The uneaten parts of the plants decay and may act as fertilizer. Tea-seed cake, often mixed with rice bran, is sometimes applied as a fish poison which later may have a fertilizing action. Rice bran, soybean meal and groundnut cake are given as food for the fish but may also serve as fertilizers. Sometimes there may be a rotation of green manuring followed by animal manuring during the growing period of the fish. With continued use of organic manures the pond bottom becomes elevated, and from time to time the ponds are drained and the muck scraped out and applied to land crops.

Information concerning the use of inorganic fertilizers in fish ponds on the Chinese mainland is lacking. With the vast agricultural problems and the huge population, it seems doubtful that inorganic fertilizers will be diverted from agriculture to fish culture.

2 HONG KONG, KOWLOON AND THE NEW TERRITORIES

Fish culture in Hong Kong and its allied territories, because of the proximity to Kwangtung, tends to follow the pattern in that province, particularly as so many of the immigrants come from that area. Where fattening of carps for the market is undertaken, a typical feature is the pig sties or cowsheds close to the pond edge. However, water difficulties have somewhat restricted this type of fish culture, and greater attention is given to the entrepôt trade in Chinese carp fry. The aim in fry holding ponds is to achieve only a maintenance ration for the fry, so excessive fertilisation with animal manures is not an advantage. Instead, green manuring may be practised, and some rice bran may also be given. In any case, with the high population pressure and the need to grow fresh vegetables on the limited area of land, animal manure is more in demand for land crops.

Some brackish-water ponds are maintained in Hong Kong, mainly culturing grey mullet (*Mugil cephalus*), but various carp species may be included as well. Although some manuring is practised, reliance is placed more on feeding with soybean flour, rice bran, groundnut cake and such foods, and these may also act as fertilizers.

A few preliminary experiments have been carried out on the use of inorganic fertilizers, but water difficulties have prevented these from being very extensive, and results are still inconclusive.

3 TAIWAN

Fish culture in Taiwan has been largely concerned with brackish-water ponds using mainly Chanos chanos, although more and more fresh-water ponds are being constructed and may be expected to increase considerably in number with the spawning of Chinese carps in Taiwan. Buffalo, cattle, pig and various other animal manures, including night soil are used as fertilizers. Rice and wheat bran, tea seed, ground nut and soybean cake and Leucaena seed are also used, although some of these may also act directly as food for the fish. Usually about four lots of organic manure are applied in a growing season.

Inorganic fertilizers are now commonly used, usually N-P-K mixtures in the proportions 8-9-2 or 8-4-2, applied at the rate of 300-500 kg per hectare per annum. This dosage is stated to give a crop of fish equal to that achieved with twice the amount of rice bran or 30 times the amount of night soil. Unfortunately the experiments on which the figures are based lacked proper controls and no attempt was made to assess the effect of the different elements separately. It is by no means certain that the addition of potassium is necessary, and in fresh-water ponds it is possible that the addition of nitrogen may also be unnecessary.

4 PHILIPPINES

Fish farming in the Philippines is still mainly concerned with brackish-water ponds involving Chanos chanos, but with hatcheries for fresh-water fish opened in various places fresh-water fish culture is spreading. In brackish-water ponds natural fertilization occurs when water is replenished by spring tides, thus bringing in a fresh supply of nutrients. In some areas tobacco dust is applied when the ponds have been filled with just enough water to cover the bottom. This acts as a fish poison against unwanted species of fish, and as it decays it serves as a fertilizer for the benthic algae. Rice bran and soybean flour are sometimes mixed with the tobacco dust to increase the fertilization effect. In other areas tea-seed cake may be used in a similar way. In both cases the ponds are stocked with fish as soon as there is abundant algal growth, by which time the toxic effect of the fish poisons has dissipated. In some areas green manuring with the leaves of certain leguminous plants is practised, the leaves being strewn over the pond bottom in the early stages of algal growth.

In fresh-water ponds cattle, pig and poultry manure have been used, but this is now giving way to the use of inorganic fertilizers.

The inorganic ferilizers used in both brackish and fresh water-ponds are N-P-K mixtures, usually in the proportions 16-20-0, 12-12-12, 12-24-12. In brackish ponds the algae are generally planted before fertilization, and the fertilizer applied at the rate of 20 g per cubic metre of water every fortnight until a heavy algal growth is achieved. Similar fertilizers are being tried in fresh-water ponds, although here the applications are given usually after fish have been stocked. Unfortunately the experiments on which the figures have been based lacked proper controls, and there was no proper assessment of the effect of the individual elements of the mixtures, so it is by no means certain that these proportions are the best.

5 INDIA

The culture of Indian carps (mainly Catla catla, Labeo rohita and Cirrhina mrigala) in fish ponds is an important industry, and various methods are used to fertilize the ponds, nearly all based on the use of organic matter. A common and simple method is by diverting sewage into fish ponds, and this is used as a means of sewage purification, notably in the Calcutta area. The possibility of oxygen deficiency in the fish ponds is a danger, but many Indian carp species have been found to stand quite low oxygen concentrations. Phenomenal crops of fish are claimed for sewage ponds, although the figures seem less impressive when critically analysed. Some experiments have been tried with very dilute sewage, with favourable results, and this suggests that sewage might be used more efficiently than it is at present.

Other materials used are cow dung stable refuse and poultry manure. Oil-seed cake is often given, theoretically as a food for the fish, but it probably acts mainly as a fertilizer. Green manuring is practised in some areas, bundles of cut grass and weeds being dumped in heaps on the bottom of the drained ponds, usually with stones or lumps of clay to hold them down. The placing of the weeds in heaps, rather than spreading them over the bottom, lessens the danger of deoxygenation of the water. Animal manures are often confined in baskets or bags for the same reason.

Inorganic fertilizers have come into use, there being no fixed method, since much of the work is still experimental. Research has tended to be centred on the use of N-P-K mixtures without adequate tests of the effect of the individual elements. This is a pity, because limnological data from many of the areas suggest that the addition of potassium is unnecessary, and with the prevalence of nitrogen-fixing bluegreen algae in so many parts of India, it seems distinctly possible that the addition of nitrogen is also unnecessary. Where phosphate alone has been used it seems to give crops as good as, if not better than, with the mixed fertilizers, but the lack of good controls in these particular experiments detracts from the value of their results.

6 INDONESIA

In Indonesia there are both extensive brackish-water ponds, based mainly on the culture of Chanos chanos, and a considerable number of fresh-water ponds, in which the main species cultured are the common carp (Cyprinus carpio), Puntius gonionotus, Tilapia mossambica and the giant gourami (Osphronemus goramy). In brackish-water ponds green manuring is commonly practised, leaves of the mangrove (Avicennia) and rice straw being strewn over the bottom of the drained pond. In fresh-water ponds cattle, horse and cow dung are used, the manure usually being placed in a small bamboo enclosure in one corner of the pond to avoid general deoxygenation of the water. Sewage has been used in some ponds but not to the extent that it is used in India.

Although some initial experiments were started on the use of inorganic fertilizers, these have not been followed up to any great extent.

7 CEYLON

Both brackish-water and fresh-water fish ponds are maintained in Ceylon, and in both cases fertilization is largely through the agency of animal manures, although sewage is used to some extent. A certain amount of green manuring is also practised. More recently experiments have been carried out using ammonium phosphate as a fertilizer in brackish-water ponds and the results seem promising, although it is questionable whether the cost of this particular fertilizer would justify its use.

8 PAKISTAN

In East Pakistan farmyard manure, cow dung and horse dung are commonly used to fertilize fish ponds, the manure usually being confined in bamboo enclosures at the corners of the ponds. Sometimes a mixture of superphosphate and cow dung is applied, three parts dung to one part superphosphate, at the rate of 555 kg/ha per annum. Oil cake is frequently added, and where available slaughter house refuse and mill sweepings are often used. Green manuring is practised, a leguminous crop being grown in the pond before flooding, or cut weeds being placed in heaps on the bottom. Methods in West Pakistan are somewhat similar, although camel dung is also available.

There seems to have been comparatively little research on the use of inorganic fertilizers alone in fish ponds in Pakistan. Such methods of fertilization might be particularly useful in semi-arid regions where organic manures are at a premium, and which would be more advantageously used to provide humus to the soil.

9 THAILAND

Fertilization of fish ponds in Thailand, as in most other Asian countries, commonly involves the use of buffalo, cow and pig manure, and not infrequently night soil is added. In some areas pig sties are built close to the water's edge, while duck pens may be built out over the water. Cut vegetation, offal, rice bran, oil cake are all thrown into the pond, and while they may form food for the fish, they also may act as fertilizers. There have been a few experiments on the use of inorganic fertilizers, but as in other Asian countries these have been more concerned with N-P-K mixtures rather than with the individual elements.

10 MALAYSIA AND SINGAPORE

Fish culture in these territories tends to fall into two main categories, the highly commercialised Chinese methods using Chinese carps, and the subsistence methods used by Malays, mainly involving "wild" fish. The Chinese system characteristically follows that of Kwangtung province, with pig sties built at the water's edge and latrines often built over the water. One or two farmers concentrate on duck breeding rather than pig rearing, and in their ponds the duck pens are built out over the water. Cut land plants such as tapioca, banana leaves, sweet potatoes, kangkong (Ipomaea repens), and sometimes rice bran are fed to the fish, and the undigested parts may also have a fertilizing action. Malays, being Muslims, are not permitted to rear pigs, so where fertilization of the pond is a practice buffalo and cattle byres are built near the water's edge, but more often than not the ponds are left unfertilized.

Research in Malacca, both in experimental ponds and commercial ponds,has demonstrated that inorganic fertilizers can be superior to organic manures, and that once a pond has been limed to neutrality only superphosphate need be added. Nitrogen fixation takes place through blue-green algae, which are stimulated by the addition of superphosphate. Studies on commercial ponds, and comparisons with ponds fertilized by superphosphate, have shown that the bulk of the algal production in commercial ponds is not digested by the fish and is virtually useless. This is why so much supplementary food has to be given. With superphosphate applications and no supplementary food, it has been demonstrated that as good, or frequently better, crops can be raised than in commercial ponds. Furthermore, it has been shown that overfertilization of ponds is possible, leading to autoshading of the plankton and a reduction of total plant production and dangers of oxygen deficiency; this may be part of the reason why commercial pnnds only give good crops when there is considerable supplementary feeding. There is some evidence from Malacca that excessive supplementary feeding may in itself lead to excessive growth of surface plankton, autoshading and oxygen deficiencies. The research in Malacca has been carried out with proper controls and on a sound statistical basis. Because the method now recommended involves so little work (only 10 man days labour per year to apply the fertilizer) and the fertilizer is so cheap (Malayan $50 for the 333 kg/ha applied) it is gradually being adopted by commercial farmers, on estates and on Federal Land Development schemes. Results in most cases have been very encouraging.

Summing up, it would be true to say that while in Asia the common methods of fertilizing fish ponds utilize organic manures, more and more evidence is acccumulating that inorganic fertilizers are not only more efficient, but are cheaper in the long run. More critical experiments are needed in the various countries to find the best inorganic fertilizer, in particular to ascertain whether potassium and nitrogen are necessary.

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APPRAISAL OF NORTH AMERICAN FISH CULTURE FERTILIZATION STUDIES

by

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Abstract

North American contributions to the aquatic fertilization literature are reviewed briefly. Although the results of these contributions make it relatively safe to predict that fertilization, either with inorganics or organics, will lead to an increase in aquatic productivity of one kind or another, little progress has been made beyond this primitive predictive stage. In particular, only three attempts have been made to monitor the fertilizer substances after they were added to the pond, and then to correlate fish production with the levels of the substances monitored. The inconsistent results obtained in these three studies, and the meagre knowledge now extant about fertilizer dynamics in aquatic systems indicate that a major revision is needed in the approach to pond fertilization problems. Two fundamental aspects of any valid approach are discussed.

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II/R-3

REVUE CRITIQUE DES ETUDES SUR LA FERTILISATION DES ETANGS DE PISCICULTURE EN AMERIQUE DU NORD

Résumé

Il s'agit d'un tour d'horizon rapide des travaux en Amérique du Nord sur la fertilisation des eaux. Les résultats de ces travaux indiquent que l'on peut prévoir, à peu près à coup sûr, que l'épandage d'engrais, soit inorganiques, soit organiques, entrainera une augmentation de la productivité aquatique en général, toutefois, pour le moment, on ne peut guère aller au-delà de ces prévisions, somme toute assez rudimentaires. En particulier, trois essais seulement ont été faits pour étudier ce que deviennent les éléments fertilisants après qu'ils ont été déversés dans l'étang et ensuite pour établir une corrélation entre la production poisson et le niveau des substances étudiées.

Les résultats contradictoires auxquels ont abouti ces trois études demeurent pour le moment et le peu de connaissances dont on dispose actuellement au sujet de la dynamique des engrais dans les systèmes aquatiques indique la nécessité d'une révision complète des méthodes employées pour étudier les problèmes de fertilisation des étangs. Deux aspects fondamentaux de toute approche valable sont examinés ici.

EVALUACION DE LOS ESTUDIOS SOBRE FERTILIZACION EN PISCICULTURA HECHOS EN NORTEAMERICA

Extracto

Se pasa revista sumariamente a los trabajos norteamericanos referentes a la fertilización de las aguas. Aunque los resultados de tales comunicaciones técnicas hacen relativamente fácil predecir que la fertilización, ya sea con sustancias inorgánicas u orgánicas, determinará un incremento de la productividad acuática de una especie u otra, pocos adelantos se han realizado que superen esta fase de primitiva predicción. En particular, sólo se han realizado tres intentos de efectuar observaciones de las sustancias fertilizantes después de adicionadas éstas al estanques, y de correlacionar la producción íctica con los niveles de las sustancias observadas. La falta de coherencia entre los resultados obtenidos en estos tres estudios y los escasos conocimientos actuales acerca de la dinámica de los fertilizantes en los sistemas acuáticos indica que es necesaria una revisión fundamental de la forma de abordar los problemas de la fertilización de los estanques. Se examinan dos aspectos fundamentales de cualquiera de estas formas válidas.

1 INTRODUCTION

The history of published scientific attempts in North America to increase aquatic productivity by addition of fertilizers covers a mere 37-year period (1929-present). Although some of the early workers in this area tended to ignore aquatic productivity outside that of fish, most fishery biologists soon realized the necessity of assessing the effects of fertilization on fish food. However, to date the assessments of these effects, both on fish and on fish food, have been singularly unsuccessful in establishing fundamental principles upon which to base predictions. One reason for this is that no one has yet mounted an aggressive and sustained study to elucidate the role played by artificial fertilization in aquatic (vertebrate or invertebrate) productivity. As a result, we are essentially no closer now to predicting results of fertilizer practices than we were 37 years ago.

In view of this, in addition to a review of the aquatic fertilization work in North America, this paper includes some thoughts about the future of fertilization experiments.

2 SUMMARY OF FERTILIZATION STUDIES

Wiebe (1929, 1930) apparently pioneered the scientific study of aquatic fertilization in North America. He experimented with both organic and inorganic fertilizers and tried to measure their effects in terms of plankton production. He found that in general fertilization enhanced plankton productivity. Shortly thereafter, Meehean (1933) and Hogan (1933) published results of experiments in which both organic and inorganic fertilizers were used. In both experiments increases in production of fish were obtained. The following year Meehean (1934) discussed theoretical aspects of fertilizer-induced productivity at various trophic levels in ponds, but no experimental data were presented. Again, Meehean (1935) considered the role of bacteria in fertilized ponds. An awareness of the importance of nutrients in the pond soil is indicated by his discussion of carbon: nitrogen ratios in fertilized and unfertilized pond bottoms. Three years later Juday and Schloemer (1938) reported on the addition of several combinations of inorganic and organic fertilizers to a small natural lake. They found that both plankton abundance and fish growth rate were increased after addition of fertilizers. Swingle and Smith (1939a, b) conducted experiments to determine the combination of inorganic nitrogen, phosphorus, potassium, and lime that would most efficiently increase plankton and fish production. In both papers success in increasing plankton and fish production was reported. Smith and Swingle (1940) studied the effects of both organic and inorganic fertilizers on plankton and fish production and found an increase in both plankton and fish. Smith and Swingle (1943) again reported increases in fish production by using various organic fertilizers, both without and with superphosphate. Meanwhile, Howell (1942) found that fertilization led to increases in plankton abundance, bottom organism abundance and fish production. Surber (1945) described the effects of various amounts and combinations of organic and inorganic fertilizers on weed and algal growth in hatching ponds. Smith and Moyle (1945) applied both organic and inorganic fertilizers to hatchery ponds and found that fertilization resulted in an increase in plankton production.

Swingle (1947) summarized earlier published fertilization data, and also discussed at some length problems and progress made in fertilization studies. Data on fish production under various regimes of fertilization were included. Smith (1948) fertilized a natural lake with inorganic N-P-K and obtained an increase in plankton production. Patriarche and Ball (1949) gathered a considerable amount of experimental data from both fertilized (inorganic N-P-K) and unfertilized ponds to show that fertilization increased the abundance of bottom organisms. Ball (1949) experimented with a combination of both organic and inorganic (N-P-K) fertilizers in hatchery ponds. Increased production of plankton, bottom organisms, and fish was obtained. Langford (1950) found that inorganic N-P-K fertilization resulted in increased abundance of plankton. Ball (1950) reported on the limnological effects of fertilizing two natural lakes with N-P-K fertilizers. Ball and Tanner (1951) discussed the effects of inorganic N-P-K fertilizers on plankton, filamentous algae, higher aquatic plants, bottom invertebrates and fish in a natural lake. They found that both plankton and fish production increased as a result of fertilization. Ball and Tait (1952) indicated that application of inorganic N-P-K fertilizers to fish ponds resulted in an increase in fish production, although the increase was not economical. Zeller (1953) found that application of inorganic N-P-K fertilizers to fish ponds resulted in an increase in plankton production. Tanner (1960) studied the chemical and physical effects of adding inorganic N-P-K fertilizers to natural lakes. McIntire and Bond (1962) found that addition of nitrogen and phosphorus to shallow ponds led to increases in plankton abundance and bottom fauna abundance.

3 CORRELATION OF FISH PRODUCTION WITH FERTILIZER SUBSTANCES IN POND WATER AND SOIL

It is of interest now to classify the experiments summarized above according to whether or not any attempt was made to find out what happened to the fertilizer elements added to the water. Although it seems that this should be an obvious and essential part of the experimental procedure, surprisingly few authors reported any such attempts. Those that did were Wiebe (1930), Meehean (1935), Juday and Schloemer (1938), Swingle and Smith (1939b), Smith and Moyle (1945), Smith (1948), Zeller (1953) and McIntire and Bond (1962). However, in all cases these attempts were limited to the indirect and rather unsatisfactory technique of analyzing water and/or soil samples for various ions that might possibly contain the fertilizer substances added; the expectation being that if, for example, $NaNO_3$ were added to the water, subsequent measurements of water or soil nitrogen would reflect this addition. Moreover, in all of these papers the significance of the water and soil analysis results was apparently based on the assumption (explicit or implicit) that as fertilizers are added to the water, the level of nutrient elements in the water increases leading to increases in plankton, bottom organisms and finally vertebrate life. Unfortunately, biological systems do not ordinarily operate in such a straightforward manner. Thus, the fact that the addition of fertilizer to a pond is followed by an increase in the levels of various chemical nutrients in the pond, does not necessarily imply a like increase in plant and animal production (as will be shown subsequently). To attempt to show that a correlation exists between fertilizer elements, as measured in the water and soil, and plant or animal production is the logical next step. Yet apparently only five papers have been published that discuss this aspect of fertilizer experiments at all, and three of these ignore entirely fish production.

The first paper that reported an attempt not only to monitor fertilizer elements after they had been added to the pond, but also to show a relation between these water and soil analyses and the subsequent fish production, was by Meehean and Marzulli (1945). The aspects of their study which are of importance here are as follows:

(1) The duration of the experiment was 86 ± 3 days (dates not provided)

(2) Sixteen 0.18 ha ponds were fertilized in the following manner: cottonseed meal[1] (two ponds), cottonseed meal plus colloidal phosphate[2] (three ponds), cottonseed meal plus lime (three ponds), cottonseed meal plus colloidal phos-

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[1] Contained 5.76 percent nitrogen

[2] Contained 24 percent P_2O_5, in addition to a number of other filler components

phate plus lime (three ponds), and one pond each with hay, hay plus lime, hay plus nitrate, hay plus colloidal phosphate, and hay plus nitrate plus colloidal phosphate.

(3) Fertilization was at the rate of 55 kg/ha cottonseed meal, 40 kg/ha colloidal phosphate, 92 kg/ha lime, and 83 kg/ha sodium nitrate, each applied weekly for 10 weeks, and beginning three weeks before fish were stocked. Hay was added in excess (amount not specified) at the beginning of the experiment.

(4) Pond waters were analyzed weekly for organic nitrogen, nitrate nitrogen, and ammonia nitrogen. Pond soils were analyzed just before draining the ponds for total carbon and total nitrogen.

(5) Production of fish (Micropterus salmoides) was determined by draining the ponds.

Without presenting any supporting graphical or statistical analyses, Meehean and Marzulli contend that their results show (1) a negative relation between fish production and amount of soil humus[1] loss (during the experimental period), and (2) a negative relation between fish production and level of organic nitrogen in water. However, their notions are based on means of fertilizer treatments, and although graphs (Figs. 1 and 2) of their data support their views, additional graphs (Figs. 3 and 4) of the individual pond data indicate quite clearly that any such simple relations just do not obtain on an individual pond basis, in particular, in replicate ponds within a treatment. Three more graphs (Figs. 5, 6 and 7) depicting the relations between fish production and various nitrogen entities add further to the impression that no meaningful relations exist between fish production and nitrogen or humus content of a pond. However, one of the major weaknesses of at least the water nitrogen data, is the considerably narrow range of values encountered. In the two studies discussed subsequently, it will be seen that wider ranges of nitrogen lead to more clear-cut, if not consistent, relations.

The second published account of an attempt to correlate fish production with measurements of fertilizer nutrients in the water was by Surber (1947). The essentials of his experimental program were:

(1) The experimental period lasted an average of 105 days (April to August).

(2) Twenty-four ponds, ranging in size from 0.09 to 0.17 ha, were fertilized with varying amounts and ratios of inorganic N-P-K mixtures, and with mixtures of organics plus superphosphate.

(3) Rates of application of the N-P-K fertilizers varied from 92 to 118 kg/ha per application, and from seven to 14 times during the season. Application rates of organic-superphosphate mixtures varied from 34 to 296 kg/ha per application, and from seven to 15 times during the season.

(4) Pond waters were analyzed every 10 days (just before fertilizers were applied) for organic, ammonia, and nitrate nitrogen.

(5) Production of fish (Micropterus dolomieu) was determined by draining the ponds.

Surber interprets his results as follows:

(1) Fish production was positively correlated with organic nitrogen level.

(2) No relation existed between fish production and ammonia nitrogen.

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[1] Humus was calculated as the average of 20x (total nitrogen in soil) and 1.7x (carbon in soil)

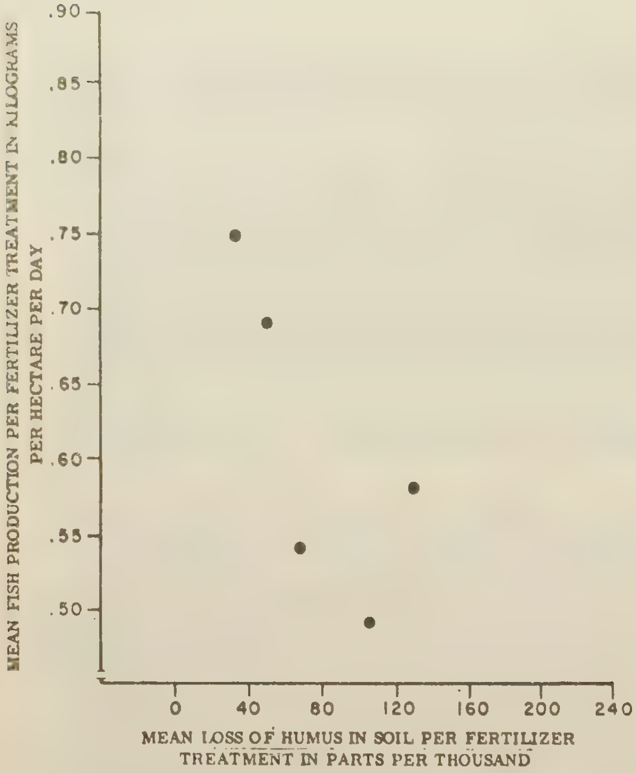

Fig. 1 Relation between mean fish production and mean quantity of soil humus lost during the experimental period on a fertilizer treatment basis. (Data from corrected values in Table I, Meehean and Marzulli, 1945)

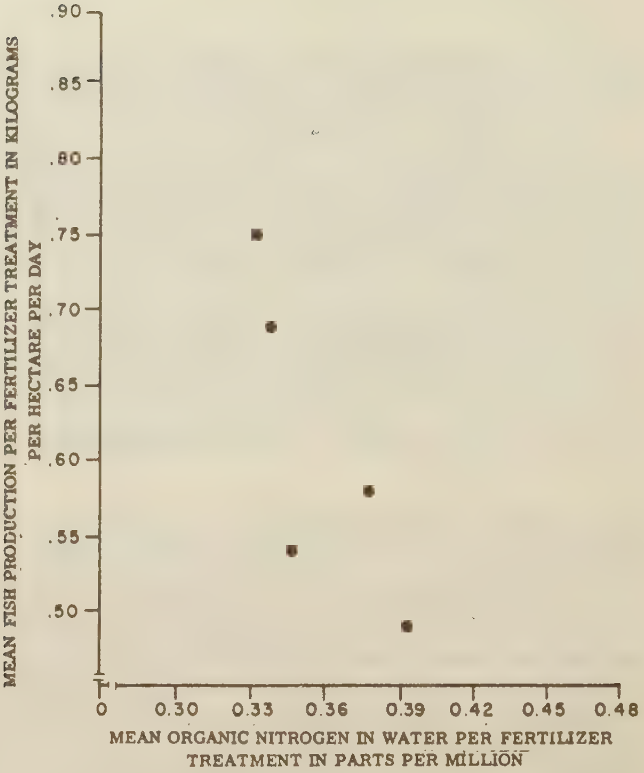

Fig. 2 Relation between mean fish production and mean quantity of organic nitrogen in pond water on a fertilizer treatment basis. (Data from Meehean and Marzulli, 1945)

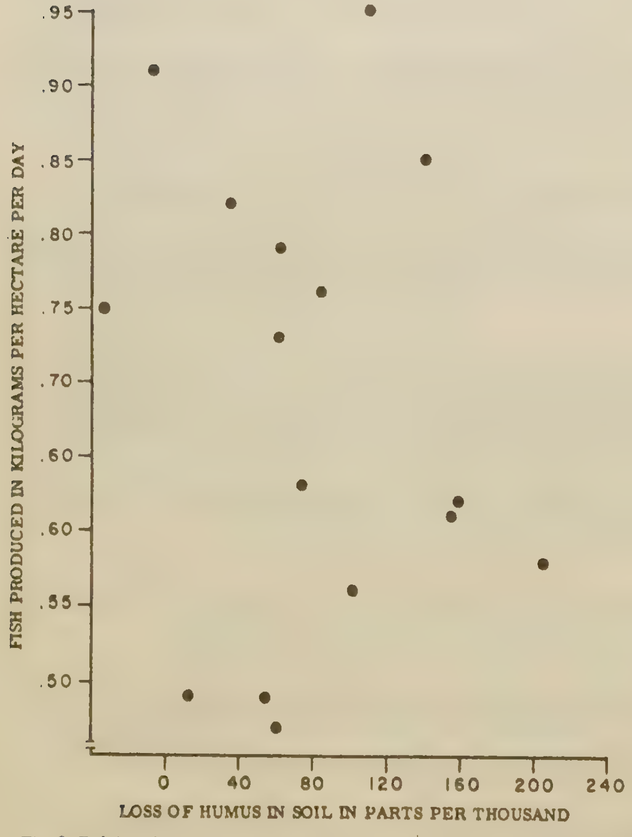

Fig. 3 Relation between fish production and quantity of soil humus lost during the experimental period. (Data from corrected values in Table II, Meehean and Marzulli, 1945)

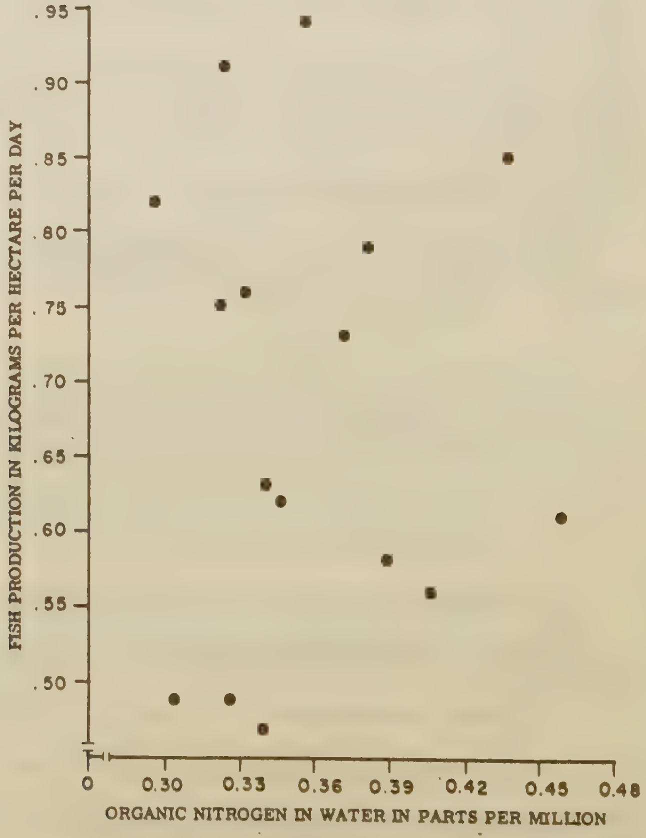

Fig. 4 Relation between fish production and mean seasonal quantity of organic nitrogen in pond water. (Data from Meehean and Marzulli, 1945)

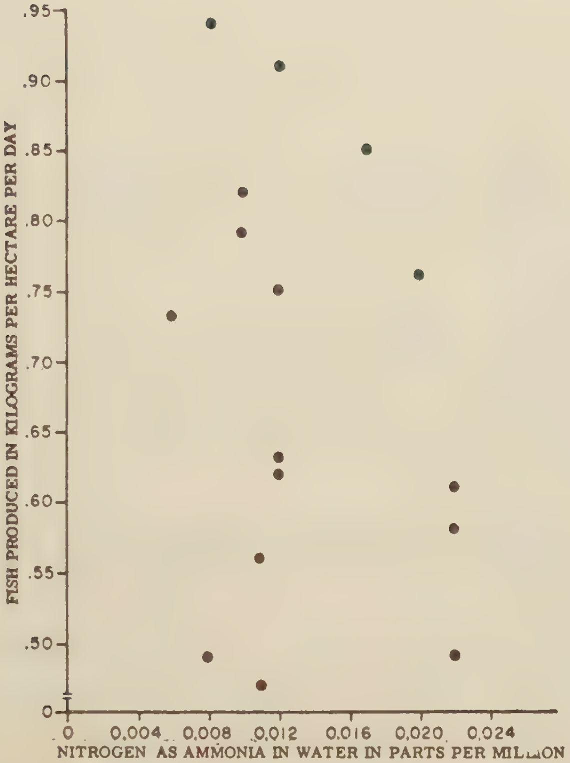

Fig. 5 Relation between fish production and mean seasonal quantity of ammonia nitrogen in pond water.
(Data from Meehean and Marzulli, 1945)

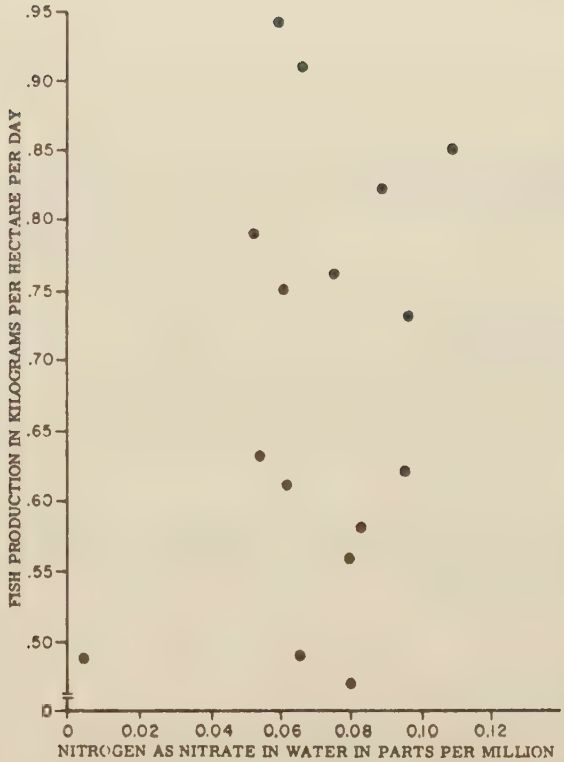

Fig. 6 Relation between fish production and mean seasonal quantity of nitrate nitrogen in water.
(Data from Meehean and Marzulli, 1945)

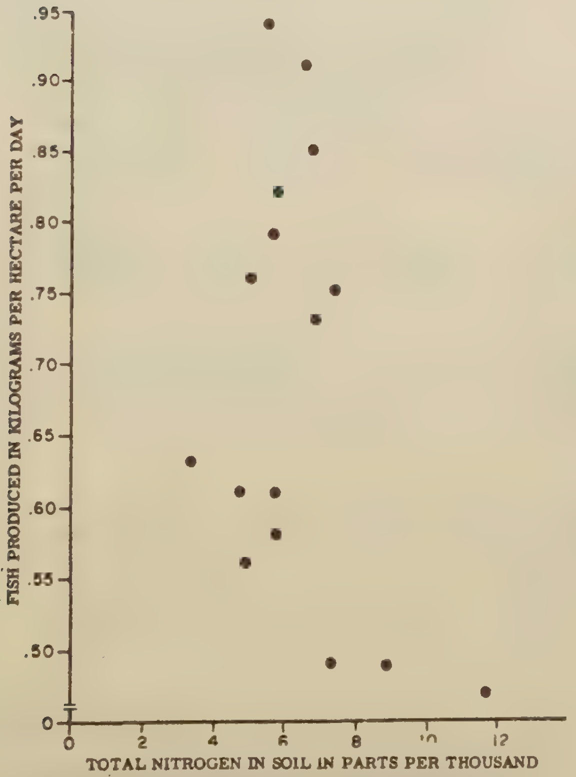

Fig. 7 Relation between fish production and quantity of total nitrogen in pond soil one week before draining.
(Data from Meehean and Marzulli, 1945)

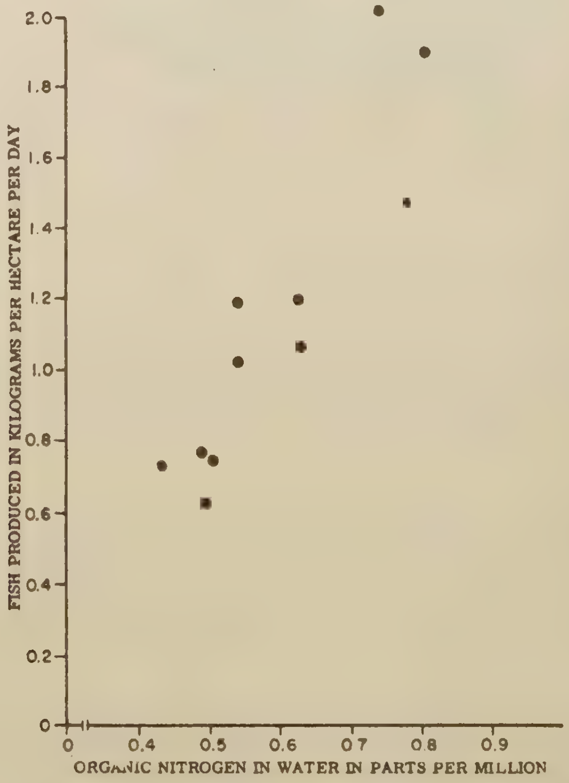

Fig. 8 Relation between fish production and mean seasonal quantity of organic nitrogen in pond water.
(Data from Surber, 1947)

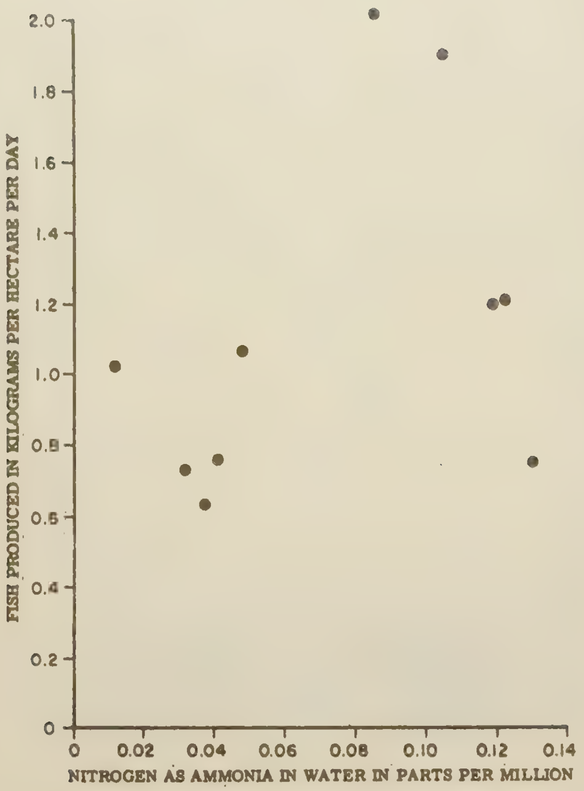

Fig. 9 Relation between fish production and mean seasonal quantity of ammonia nitrogen in pond water. (Data from Surber, 1947)

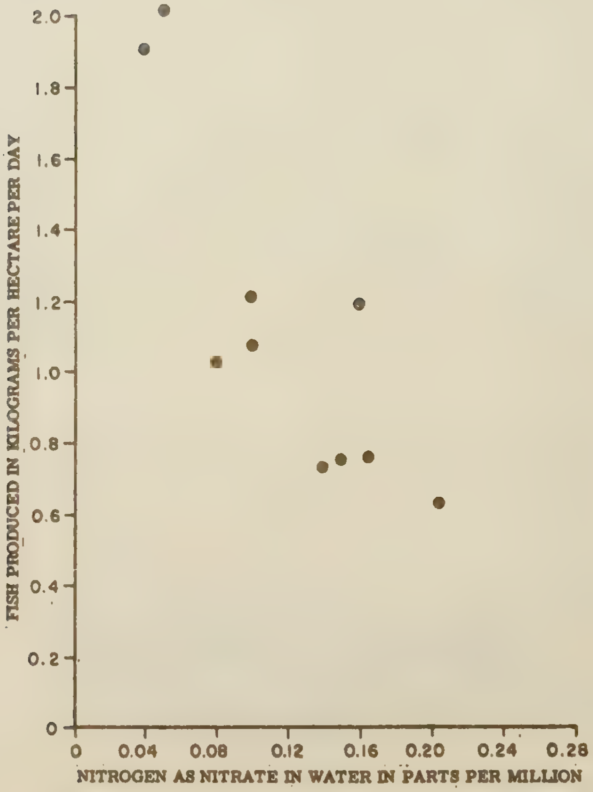

Fig. 10 Relation between fish production and mean seasonal quantity of nitrate nitrogen in pond water. (Data from Sueber, 1947)

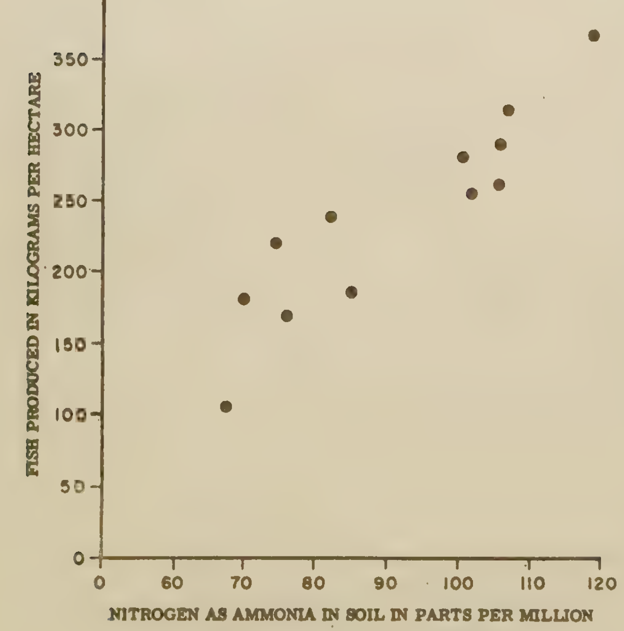

Fig.11 Relation between fish production and mean seasonal quantity of ammonia nitrogen in pond soil. (Data from Gooch, 1962)

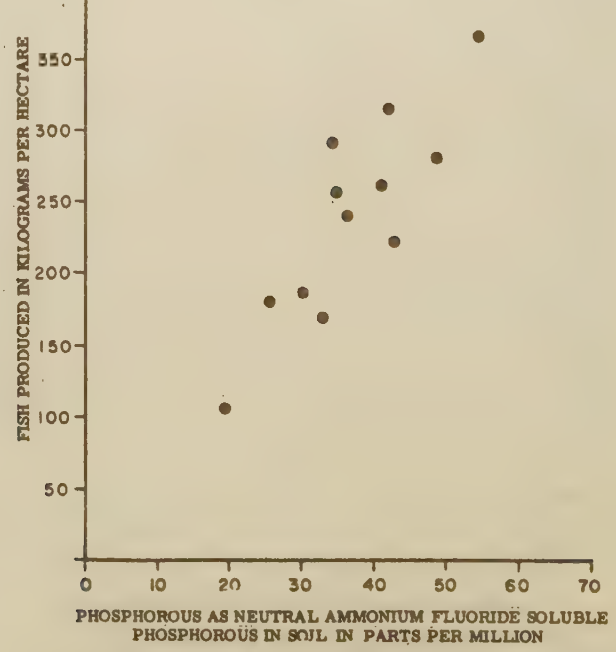

Fig. 12 Relation between fish production and mean seasonal quantity of neutral NH_4F soluble phosphorus in pond soil. (Data from Gooch, 1962)

(3) The relation between fish production and nitrate nitrogen possibly was negative.

Unfortunately Surber provides no statistical support for the foregoing interpretations. On the other hand, graphs (Figs. 8, 9 and 10) derived from the data indicate that his conclusions are sound; in fact, the negative correlation of fish production and nitrate nitrogen appears to be stronger than admitted by Surber.

A more serious defect in the data, however, is the fact that they are presented only in terms of fertilizer treatment means. Since we saw in the review of Meehean and Marzulli's (1945) paper that correlations based on treatment means provided a picture considerably different from that provided by correlations based on individual pond values, we still cannot consider that we have obtained unequivocal evidence of meaningful relations between fish production and measured amounts of fertilizer substances.

In addition to the two foregoing studies reported, in which the relations between nutrient levels in fertilized pond water and soil and the production of fish were examined, a third study (Gooch, 1962) has been conducted. The relevant features of this work are as follows:

(1) The duration of the experiment was from March to November, 1960.

(2) Four 0.1 ha culture ponds averaging 1.2 m in depth each were fertilized with 8-8-2 and 0-8-2 ($N-P_2O_5-K_2O$), and four ponds were unfertilized.

(3) Fertilization was at the rate of 110 kg/ha per application, with 10 applications during the season.

(4) Prior to 1959 the 12 experimental ponds had received fertilizers for 15 years.

(5) Pond waters and soils both were analyzed periodically (*ca.* monthly) during the experimental period for nitrogen (organic, ammonia, nitrate, and nitrite) and phosphorus (various inorganic fractions). In all, 11 different chemical entities were determined in each pond.

(6) Production of fish (*Cyprinus carpio*) in the ponds during the season was determined by draining the ponds.

Simple and multiple correlations between the weights of fish produced in each pond and the mean seasonal amounts of the 11 different nitrogen and phosphorus fractions in each pond were calculated. Many of the correlations involved variables that were combinations of two, three or four of the individual 11 quantities. The significant findings may be listed as follows:

(1) Considering simple correlations only, and based only on the 11 original variables, fish production was most highly correlated with nitrogen in the form of soil ammonia ($r^2 = 0.83$, Fig. 11), and one of the phosphorus fractions (NAFSP[1/]) in the soil ($r^2 = 0.79$, Fig. 12). Although the correlations with nitrogen fractions in the water were not as pronounced, there was no doubt that none were negative (Figs. 13, 14 and 15), contrary to the results of Surber (1947).

(2) Considering two-variable multiple correlations involving only the individual 11 chemical quantities, fish production was most highly correlated ($R^2 = 0.94$) with the combination of soil ammonia and NAFSP.

[1/] NAFSP = neutral NH_4F soluble phosphorus, which represents most aluminium phosphates, a small amount of iron phosphates, and loosely bound phosphorus.

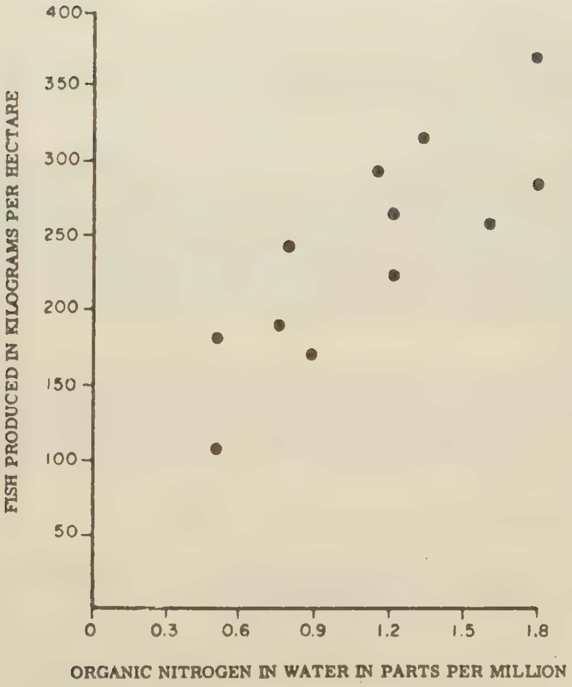

Fig. 13 Relation between fish production and mean seasonal quantity of organic nitrogen in pond water. (Data from Gooch, 1962)

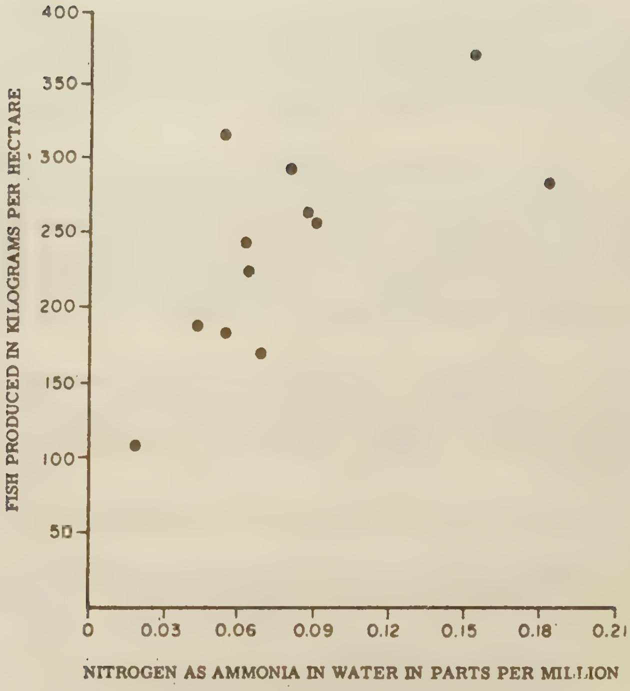

Fig. 14 Relation between fish production and mean seasonal quantity of ammonia nitrogen in pond water. (Data from Gooch, 1962)

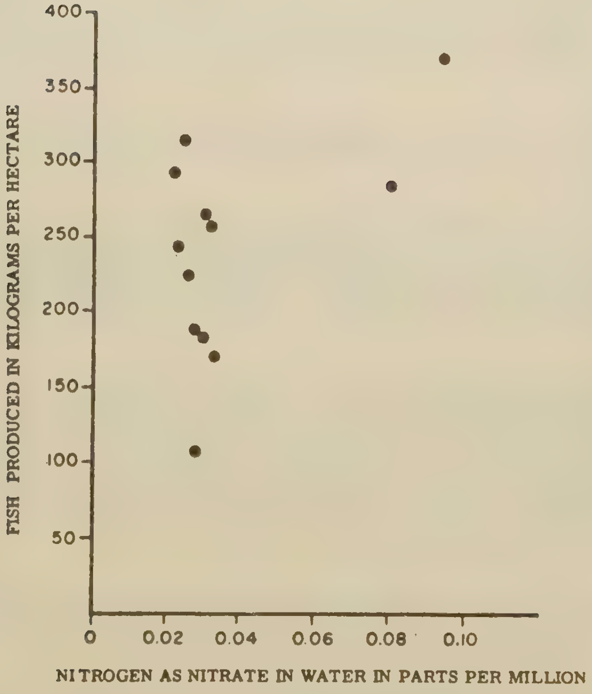

Fig. 15 Relation between fish production and mean seasonal quantity of nitrate nitrogen in pond water. (Data from Gooch, 1962)

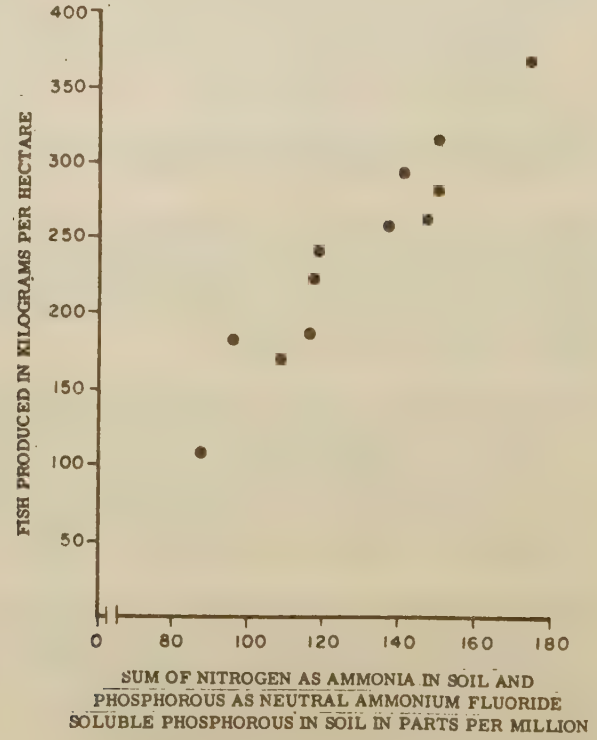

Fig. 16 Relation between fish production and sum of mean seasonal quantities of ammonia nitrogen in soil and neutral NH_4F soluble phosphorus in soil. (Data from Gooch, 1962)

(3) Considering simple correlations involving combined forms of the 11 individual variables, fish production was most highly correlated ($R^2 = 0.93$, Fig.16) with the sum of soil ammonia nitrogen and NAFSP.

In comparing the relations between fish production and various fertilizer nutrients that were obtained in the three studies summarized above, it is clear that (as pointed out previously) no obvious and consistent relations exist, or at least are not perceivable with the crude methods now in use by fish culturists. In fact, the art of pond fertilization is in such a primitive state that we are unable to cope with inconsistent relations such as those exhibited. What is of more importance, however, at this stage of development is considering the implications of the following two facts. First, the results of both Surber (1947) and Gooch (1962) show that the relationships of fish production to nutrient levels as measured in the pond soil and water are considerably more clear-cut than those between fish production and the levels of fertilizers applied. Stated another way, the evidence clearly indicates that, from amounts of fertilizer applied, one cannot infer accurately and consistently the amounts of nutrients in the pond soil or water, or the weights of fish produced.

Second, it has been demonstrated at least once (Gooch, 1962) that, in small unstratified culture ponds, fish production was more highly correlated with fractions of both nitrogen and phosphorus in the pond soil than with those in the pond water; furthermore, these correlations were demonstrated on an individual pond basis, a test that all such correlations must pass in order to be considered valid.

The first point may be considered obvious, but the fact is that the majority of published studies in North America ignore entirely both this point and the second.

4 THE FUTURE OF POND FERTILIZATION EXPERIMENTS

In pond fertilization experimental programs in North America the amount of information gained from the input of energy (in terms of money, time and physical effort) is exceedingly small. Thus, in summarizing the results of 37 years of North American experiments in aquatic fertilization, we have seen that in the majority of cases fertilization resulted in higher productivity of the aquatic system, in one sense or another. We can, however, say little more than this. For example, the pond does not exist for which it is known how much of what kinds of fertilizer elements are necessary to maximize the fish production relative to the cost of fertilizer. Although it may be argued that such a pond can never exist, it seems reasonable to expect that we can narrow considerably the wide gap existing between what we know now and this rather ideal situation.

The key to the problem lies in realizing that we must find out what happens, under what conditions, to the fertilizer elements after they have entered the pond. We have seen that in a few cases attempts were made to monitor the fertilizer nutrients after they had been added to the pond system. Unfortunately, the experimental designs of many of these studies were such that no valid inferences could be made regarding a cause and effect relation between what was added to the pond and what was measured in the water and soil. That is, the fact that the total nitrogen content in pond water increased following application of fertilizer containing nitrogen cannot be used as an argument that the latter directly caused the former. Thus, if the fertilizer also contained phosphorus, one other possible explanation is that the rise in nitrogen in the pond was created by a rise in activity of nitrogen-fixing bacteria which were in turn stimulated by the phosphorus. On the other hand, as implied previously, the usual technique of analyzing pond water and soil samples for various fractions of fertilizer elements can never lead to a satisfactory solution of the continually observed inconsistent results of fertilization experiments.

What we need are methods (for example use of radio-active tracers or "heavy" elements) that permit direct and unequivocal monitoring of the fertilizer elements so that we can find out what exactly happens, for example, to the nitrogen that enters the pond as $NaNO_3$. That is, how much is utilized by phytoplankton, by bottom organisms, and finally, by fish? It is not inconceivable that through bacterial action most of the nitrogen might be shunted aside in the elemental form before it can enter the pathways that lead to the higher trophic levels. Only by knowing the various cycles and "dead end" routes into which the fertilizer elements are passing, not only on a monthly or seasonal basis, but also on a basis of, for example, 10 or 20 years, can any semblance of a valid theory about the role of fertilizers in influencing aquatic productivity be advanced. Since experience warns us that the results of such studies will differ considerably from one region to another, and even from one pond to another, or in the same pond from year to year, any theories that are constructed will need to take such variations into account.

Another facet of nutrient cycles that demands consideration is the rate at which they operate. The total biomass produced during a given period of time depends on the rate of production of this biomass, but it is unrelated to the standing crop at any particular time. Analogously, we may say: the levels of nutrients as measured periodically in water or soil cannot be unequivocally interpreted as a measure of productivity of the pond system; it is the rate at which these nutrients are used, that is, the rate at which they cycle through the system, that determines the productivity of the system. When this point is incorporated into the thinking of pond fertilization scientists and followed up by adequate and meaningful experimental programs to study rates of cycling of fertilizer nutrients, we should be considerably closer to understanding the vagaries of pond fertilization results.

5 REFERENCES

Ball, R.C., 1949 Experimental use of fertilizers in the production of fish-food organisms and fish. Tech.Bull.Mich.agric.Exp.Sta., (210):28 p.

__________, 1950 Fertilization of natural lakes in Michigan. Trans.Amer.Fish.Soc., 78(1948): 145-55

Ball, R.C. and H.D. Tait, 1952 Production of bass and blue-gills in Michigan ponds. Tech. Bull.Mich.agric.Exp.Sta., (231):24 p.

Ball, R.C. and H.A. Tanner, 1951 The biological effects of fertilizer on a warm-water lake. Tech.Bull.Mich.agric.Exp.Sta., (223):32 p.

Gooch, B.C., 1962 Preliminary observations on the residual nature of nitrogen in ponds and its significance to fish production. Auburn, Alabama, U.S.A., Auburn Univ. (MS)

Hogan, J., 1933 Experiments with commercial fertilizers in rearing largemouth black bass fingerlings. Trans.Amer.Fish.Soc., 33:109-19

Howell, H.H., 1942 Bottom organisms in fertilized and unfertilized fish ponds in Alabama. Trans.Amer.Fish.Soc., 71(1941): 165-79

Juday, C. and C.L. Schloemer, 1938 Effect of fertilizers on plankton production and on fish growth in a Wisconsin lake. Progr.Fish Cult., 40:24-7

Langford, R.R., Fertilization of lakes in Algonquin Park, Ontario. *Trans.Amer.Fish.*
1950 *Soc.*, 78(1948):133-44

McIntire, C.D. and C.E. Bond, Effects of artificial fertilization on plankton and
1962 benthos abundance in four experimental ponds. *Trans.Amer.Fish.Soc.*,
91(3):303-12

Meehean, O.L., The role of fertilizers in pond fish. *Trans.Amer.Fish.Soc.*, 33:103-9
1933

__________, The role of fertilizers in pond fish production. 2. Some ecological
1934 aspects. *Trans.Amer.Fish.Soc.*, 64:151-4

__________, The dispersal of fertilizing substances in ponds. *Trans.Amer.Fish.Soc.*
1935 65:184-8

Meehean, O.L. and F. Marzulli, The relationship between the production of fish and
1945 the carbon and nitrogen contents of fertilized fish ponds. *Trans.Amer.Fish.*
Soc., 73(1943):262-73

Patriarche, M.H. and R.C. Ball, An analysis of the bottom fauna production in fertilized and unfertilized ponds and its utilization by young-of-the-year fish.
1949 *Tech.Bull.Mich.agric.Exp.Sta.*, (207):35 p.

Smith, E.V. and H.S. Swingle, Effect of organic and inorganic fertilizers on plankton
1940 production and blue gill bream carrying capacity of ponds. *Trans.Amer.*
Fish.Soc., 69(1939):257-62

__________, Organic materials as fertilizers for fish ponds. *Trans.Amer.Fish.Soc.*,
1943 72(1942):97-102

Smith, L.L. and J.B. Moyle, Factors influencing production of yellow pike-perch
1945 *Stizostedion vitreum vitreum*, in Minnesota rearing ponds. *Trans.Amer.Fish.*
Soc., 73(1943):243-61

Smith, M.W., Preliminary observations upon the fertilization of Crecy Lake, New Brunswick.
1948 *Trans Amer.Fish.Soc.*, 75(1945):165-74

Surber, E.W., The effects of various fertilizers on plant growths and their probable
1945 influence on the production of smallmouth black bass in hard-water ponds.
Trans.Amer.Fish.Soc., 73(1943):377-93

__________, Variations in nitrogen content and fish production in smallmouth black
1947 bass ponds. *Trans.Amer.Fish.Soc.*, 74(1944):338-49

Swingle, H.S., Experiments on pond fertilization. *Ala.Agric.Exp.Sta.Bull.*, (264):34 p.
1947

Swingle, H.S. and E.V. Smith, Fertilizers for increasing the natural food for fish in
1939a ponds. *Trans.Amer.Fish.Soc.*, 68(1938):125-34

__________, Increasing fish production in ponds. *Trans.N.Amer.Wildl.Conf.*, 4 (1939):
1939b 332-8

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Tanner, H.A., Some consequences of adding fertilizer to five Michigan lakes. Trans.
1960 Amer.Fish.Soc., 89(2):198-205

Wiebe, A.H., Investigations on plankton production in fish ponds. Bull.U.S. Bur.Fish.,
1930 (46):137-76

Wiebe, A.H., R. Radcliffe and F. Ward, The effects of various fertilizers on plankton
1929 production. Trans.Amer.Fish.Soc., 59:54-105

Zeller, H.D., Nitrogen and phosphorus concentrations in fertilized and unfertilized
1953 farm ponds in central Missouri. Trans.Amer.Fish.Soc., 82(1952):281-8

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INFLUENCE OF SOIL ON THE CHEMISTRY OF WATER IN RELATION TO PRODUCTIVITY

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Abstract

Systems in which mud influences the chemistry of water are described. The rapid disappearance of phosphates from water after fertilizing can be caused by:

1) the iron-sulphur-phosphorus system

2) the calcium-carbonate-phosphorus system

3) the uptake by bacteria and algae (polyphosphates).

The first system is very sensitive to the redox-potential in the water or in the mud itself. Therefore the importance of measuring the oxygen demand of the mud is stressed, as this process partly determines whether the mud can become anaerobic below the surface layer or not. The systems 1) and 2) are discussed in detail and are summarized. Other sorption processes, like the iron-humus-phosphorus system and the iron- or aluminium-silicon-humus systems, are also discussed. The need for much more experimental work concerning the role of these systems is stressed.

Experiments on the exchange of radiophosphorus between mud and water are described. It is necessary to distinguish between exchange and sorption processes, as has been done, for example, by Olsen. The radiophosphorus experiments often point to a high velocity of the exchange process, but there are few experiments, if any, in which the chemical nature of the active substance in the mud is well understood.

The sorption of potassium on mud is discussed. A study of the literature yielded no experimental proof of this process.

Little experimental work has been done on the mineralization of nitrogen and silicon from mud. As far as nitrogen mineralization is concerned, the only function of mud seems to be the breakdown of small quantities of not easily mineralizing substances. Perhaps it is more important that mud can convert nitrate to ammonia, even in the presence of oxygen up to 0.4 mg per litre water.

The mineralization of silicon from diatoms probably takes place completely in the mud. Nothing is known of the determining factors.

INFLUENCE DU SOL SUR LA COMPOSITION CHIMIQUE DE L'EAU ET SES EFFETS SUR LA PRODUCTIVITE

Résumé

Cette communication décrit les systèmes dans lesquels la vase a une influence sur la composition chimique de l'eau. La disparition rapide des phosphates après épandage d'engrais dans l'eau peut avoir plusieurs origines:

1) Le système fer-soufre-phosphore
2) Le système calcium-carbonate-phosphore
3) L'absorption par les bactéries et les algues (polyphosphates).

Le premier système est extrêmement sensible au potential redox de l'eau ou de la vase elle-même. Il faut donc accentuer l'importance de mesurer la consommation d'oxygène de la vase, car c'est en partie ce processus qui détermine si la vase peut devenir anaérobie au-dessous de la couche superficielle. Les systèmes 1) et 2) sont examinés en détail et résumés. D'autres processus de sorption, comme le système fer-humus-phosphore et le système fer-ou aluminium-silice-humus, sont également étudiés. L'auteur insiste sur la nécessité de poursuivre les travaux expérimentaux concernant le rôle de ces systèmes.

Il décrit des expériences sur les échanges de phosphore radio-actif entre la vase et l'eau. Il convient de distinguer entre le processus d'échange et le processus de sorption, comme l'a fait, par exemple, Olsen. Les expériences faites avec du phosphore radio-actif indiquent souvent une grande rapidité dans les échanges, mais il n'y a pratiquement pas eu d'expériences où la nature chimique de la substance active de la vase soit connue.

La possibilité de fixation par sorption du potassium sur la vase est examinée. Aucun des travaux publiés dont l'auteur a eu connaissance ne fournit la preuve expérimentale de ce processus.

Peu d'expériences ont été faites sur la minéralisation de l'azote et de la silice contenues dans la vase. En ce qui concerne la minéralisation de l'azote, la seule fonction de la vase semble être la fragmentation des faibles quantités de substances qui ne sont pas facilement minéralisables. Il est peut-être plus important de noter que la vase peut transformer l'azote nitrique en azote ammoniacal, même en présence de quantités d'oxygène allant jusqu'à 0,4 mg par litre d'eau.

La minéralisation de la silice provenant des diatomées a probablement lieu entièrement dans la vase. On ne sait rien des facteurs qui déterminent ce processus.

INFLUENCIA DEL SUELO EN LA QUIMICA DEL AGUA EN RELACION CON LA PRODUCTIVIDAD

Extracto

Se describen formas en las que el fango influye en la composición química del agua. La rápida desaparición de los fosfatos del agua después de la fertilización puede ser causada por:

1) el sistema hierro-azufre-fósforo;
2) el sistema calcio-carbonato-fósforo;
3) la absorción por bacterias y algas (polifosfatos).

El primer sistema es muy sensible al potencial redox del agua o del fango. Por esto, se acentúa la importancia de medir la exigencia de oxígeno del fango, ya que este proceso determina, en parte, si el fango puede volverse anaerobic debajo de la capa superficial o no. Se examinan tambien otros procesos de sorción como el sistema hierro-humus-fósforo y el sistema hierro- o aluminio-silicio-humus. Se pone de relieve la necesidad de realizar muchos más trabajos experimentales basados en estos sistemas.

Se describen experimentos sobre el intercambio de fósforo radioactivo entre el fango y el agua. Es preciso distinguir entre procesos de intercambio y de sorción, como ha hecho, por ejemplo, Olsen. Los experimentos con fósforo radioactivo indican frecuentemente una elevada velocidad del proceso de intercambio, pero existen pocos experimentos, si es que existen algunos, en los que se conozca la naturaleza química de la sustancia activa en el fango.

Se examina la sorción de potasio en el fango. Una investigación de las obras publicadas al respecto no dio ninguna prueba experimental de este proceso. Se han realizado pocos trabajos de tipo experimental sobre la mineralización del nitrógeno y del silicio del fango. Por lo que se refiere a la mineralización del nitrógeno, la única función del fango parece ser la descomposición de la pequeña cantidad de sustancias no fácilmente mineralizantes. Quizás es más importante el hecho de que el fango puede convertir nitrato en amoníaco incluso en presencia de oxígeno hasta 0,4 mg por litro de agua. La mineralización del silicio de las diatomeas probablemente se efectúa por completo en el fango. Nada se sabe de los factores determinantes.

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1 INTRODUCTION

For the growth of fish a combination of solar energy and inorganic nutrients in a closed system, called a "food chain", is essential. In the primary production stage, the first link of the food chain, the nutrients, are usually dissolved in water. Further on in the food chain they may also be bound to organic substances in particulate matter. The concentrations of the dissolved nutrients result from an equilibrium between their disappearance into organisms and reappearance in the mud and gas phase.

This paper is concerned with the chemical mechanism by which the mud influences the concentrations of dissolved nutrients. Only experiments directly connected with the mechanism of exchange processes are discussed, whereas all "circumstantial evidence" is omitted. When for example a fertilizer is added to water and it leads to an increased production of fish in the next year, this experiment does not prove an adsorption of the fertilizer by the mud, nor does it give any information about the mechanism of a possible adsorption.

The elements that are supposed to be "stored" in mud are the following: Fe, P, N, Ca, K, Si, and trace elements (for the latter see Gorham and Swaine, 1965). Furthermore mud plays an important role in the generation of organic substances (especially vitamins), the O_2 balance of water, the pH regulation and the sulphur cycle. In most exchanges or sorption processes two or three elements are closely connected. It is therefore not possible to discuss the different elements separately.

Nearly nothing is known about the production of organic substances (including vitamins) by the mud, except that humic substances are formed there. Current research in this field (see, for example, Povoledo, 1964; Ryhänen, 1964) has not yet produced any data relating to the subject under discussion.

As the production of vitamins probably takes place by bacterial conversions, this process may also occur in the mud, but nothing is known of the determining factors. Better knowledge of these problems might be useful for increase of production.

2 THE IRON-SULPHUR-PHOSPHORUS SYSTEMS

Much work on this system has already been done by Einsele (1936; 1937; 1938), Ohle (1937; 1938) and Mortimer (1941; 1942). When a lake stratifies and the hypolimnion becomes anaerobic (and the redox potential therefore falls) (Pearsall and Mortimer, 1939) the iron in the mud (present in ferric form) will be reduced to the ferrous form. The reducing agent may be H_2S, formed by anaerobic process of sulphate reduction by anaerobic bacteria like Desulfovibrio desulfuricans:

$$H_2SO_4 + \text{H donor} \longrightarrow H_2S + 2\,H_2O$$

According to Einsele (1936), the reduction of the Fe^{+++} follows the reaction

$$2\,Fe^{+++} + S'' \longrightarrow 2\,Fe^{++} + S$$

The Fe^{++} appears in the water and must be balanced by HCO_3' ions. The course of this process is unknown; the reaction

$$FeS + 2\,CO_2 + 2\,H_2O \longrightarrow Fe\,(HCO_3)_2 + H_2S$$

proposed by Einsele (1936) and Ohle (1937) seems improbable, as can be calculated from the pK's of H_2CO_3 and H_2S.

The reduction system has been studied by Einsele (1936), who found that the reaction is not stoechiometric. In his experiments an excess of H_2S was necessary to obtain a 100 percent resolution of the iron. It is not clear why the first formed

Fe^{++} ions are not directly precipitated by the remaining H_2S. FeS is a very stable, insoluble compound even under aerobic conditions. It is, however, not impossible that FeS dissolves more easily when in contact with mud (Hogendijk, unpublished) than in inorganic chemistry.

Although there are no indications in the literature, it seems worth-while to investigate whether the H donor in the first reaction can reduce the iron directly. This H donor originates from the mud or directly from the extracellular products formed during photosynthesis. As this production is beyond the scope of this review, I only mention the papers of Hellebust (1965) and the work of Fogg (1964) and his co-workers (Nalewajko, 1963; Fogg and Nalewajko, 1963). The second source of the H donor consists of organic compounds released by autolysis or breakdown of dead organisms by bacteria. Golterman (1960; 1964; 1966) has shown that during these decomposition processes many products are liberated and rapidly converted by bacteria. These processes occur in both water and mud, so that it is easily understood that reduction of sulphate takes place mainly in mud, although Sorokin (1966) has shown that it happens also in water.

The quantitative experiments on the Fe-S relationship must be repeated, especially because the calculations of Einsele (1937) are partly incorrect, due to the use of wrong (out-of-date?) dissociation constants of the H_2S equilibria.

At the overturn, the dissolved ferrous iron is oxidized by O_2. As the pH is usually above 6 the Fe^{+++} formed is precipitated as $Fe(OH)_3$, the starting point of the second reaction. When phosphates are present these are co-precipitated, either as $FePO_4$ or adsorbed to $Fe(OH)_3$. The last question is not a purely academic one, as adsorbed phosphorus is much more easily exchangeable than phosphorus in $FePO_4$. It is not known whether algae can grow on the practically insoluble $FePO_4$. Armstrong and Harvey (1951) mentioned the growth of a P-depleted diatom on $FePO_4$, but this growth probably followed the hydrolysis of the $FePO_4$ that takes place in sea water, as they demonstrated by the decrease in pH from 8 to 7, where the process stopped. On the other hand Ohle (1937; 1938) has demonstrated that the phosphorus bound to $Fe(OH)_3$ precipitate can be dissolved by H_2S or H_2CO_3 and $Ca(HCO_3)_2$ more easily than the phosphate of $FePO_4$. Einsele (1938) described the adsorption of phosphate onto $Fe(OH)_3$ with the adsorption isotherm $C_d = K\ C_a^n$, in which C_d is the phosphorus concentration in the water and C_a the amount of phosphate adsorbed to 1 mg $Fe(OH)_3$ and n and K are constants. The amount of $Fe(OH)_3$ in the mud is mostly unknown, which fact makes the formula practically inapplicable.

The question whether these processes are important in fish ponds, brings us to the work of Mortimer (1941; 1942). He found that a redox potential below 0.2 V (associated with an oxygen concentration of 0.1 mg/l) causes reduction of iron and also that this redox potential is present in "oxidized" mud even a few centimetres below the mud-water surface. Factors influencing the thickness of the oxidized microzone are turbulent displacement of the uppermost sediments into the overlying aerated water, as well as the reducing power of the sediment itself (and therefore probably the productivity of the whole lake or pond) (Gorham, 1958). Edwards (1958) showed that introduction of larvae of *Chironomus riparius* caused an increased depth of the surface layer of sludge where the redox potential is high. Hayes, Reid and Cameron (1958) presented some evidence that the real oxidized layer is only one mm thick or less, by placing iron and copper wires vertically in the mud. The break in the electrode curve at about one cm is supposed to be caused by such factors as wind induced currents and presence of sulphide, or by pushing down the redox layer by the electrode. Most of the phosphorus adsorbed by the mud appeared to be in a layer of less than one mm, when determined by radio-autograph technique.

For scientific and practical purposes we should know what happens to this adsorbed phosphate when this oxidized crust is reduced, either by action from above, due to the overlying water becoming anaerobic, or by action from underneath, when a new deposit had been placed on the crust layer and the mud itself becomes anaerobic because of the O_2 demand. Furthermore we should know how far the oxidized crust inhibits all transport upwards and downwards.

In very productive waters - which most fish ponds are - there is bound to be a very rapid mineralization of the organic material together with a high uptake of O_2 (see section 9 below). So it is likely that the mud is mainly in a reduced state and that a "micro-stratification" occurs. In this case the phosphorus added to a fish pond as a fertilizer is very likely to be made insoluble by the formation of $FePO_4$.

Fair, Moore and Thomas (1941) described a loss of iron from deposits, probably by reduction of iron followed by an active transport from the mud by gas bubbles (methane or hydrogen?) and the flow of water. When there is no movement in the water the ferrous compounds are oxidized and form the layer of $Fe(OH)_3$ as described by Mortimer (1950).

3 THE CALCIUM-CARBONATE-PHOSPHORUS SYSTEM

The water of fish ponds generally has a high calcium content, as lime is used widely as a fertilizer. Schäperclaus even advises adding $CaCO_3$ or CaO to acid Ca-poor ponds to raise the pH to values of about 8 in order to increase production. However, a certain optimum calcium concentration may probably not be surpassed because of the danger of formation of insoluble compounds.

The solubility of $CaCO_3$ is low (± 15 mg/ℓ), but is increased in the presence of CO_2 (50-60 mg/ℓ at a CO_2 concentration of 0.00032 atmo.). The solubility product is $\pm 1 \times 10^{-8}$.

In a solution containing 1.8 milliequiv. HCO_3 - ions with a pH of 8.6, which solution is in equilibrium with the CO_2 in the air at 20°C [Maciolek (1954) gives the pH range for fish ponds as 6.5 - 9, with an optimum around 8] the concentration of the CO_3 is

$$(CO_3'') = K_2 \frac{[HCO_3']}{[H^+]} = \frac{5.6 \times 10^{-11} \times 1.8 \times 10^{-3}}{10^{-8.6}} = 4 \times 10^{-5} \text{ M}/\ell$$

and therefore the calcium concentration is

$$[Ca^{++}] = \frac{10^{-8}}{4 \times 10^{-5}} = 2.5 \times 10^{-4} \text{ Mol}/\ell = 10 \text{ mg Ca}/\ell$$

This means that the addition, in this solution, of more than 10 mg/ℓ of calcium causes the precipitation of $CaCO_3$.

The given example is not an unlikely one; during photosynthesis the pH may easily be higher. The figures must be recalculated for each pond after determination of its pH and HCO_3' ion concentration. (pH indicator papers are not reliable, as the quantity of the indicator is not small compared with the quantity of the buffering ions in water).

Up till now the precipitation of $CaCO_3$ was not considered to be harmful. Schäperclaus even supposes that a stock of $CaCO_3$ in the mud precipitates harmful organic acids produced by the mud. But even in the case of the very insoluble calcium oxalate this effect is not produced, as long as the calcium concentration is 10 mg/l, before the oxalate concentration surpasses 0.7 mg/l. (The solubility product of calcium oxalate is 2×10^{-9}; therefore the oxalate concentration in equilibrium with a calcium concentration of

$$2.5 \times 10^{-4}\ \text{M is } \frac{2 \times 10^{-9}}{2.5 \times 10^{-4}}\ \text{M} = \frac{2 \times 10^{-9}}{2.5 \times 10^{-4}} \times 88 \times 10^{3}\text{mg} = 0.7\ \text{mg}/\ell\,)$$

For the whole water mass this seems to be an unattainable concentration. The calcium salts of many other organic acids are even more soluble than calcium oxalate. Furthermore, no experiments could be found in the literature that proved the production of harmful organic acids by mud.

The second advantage mentioned by Schäperclaus, the buffering capacity against acid production, is again hypothetical; a saturated $CaCO_3 + Ca(HCO_3)_2$ solution, without any extra solid $CaCO_3$ is more than sufficient to buffer the quantities of acid produced by mud in a natural system. When a mud (with a metabolic rate: O_2 uptake of 5 $g/m^2/day$, see Section 9) produces 10 percent of this amount as an organic acid with 3 C atoms under anaerobic conditions, it produces

$$\frac{10}{100} \times \frac{1}{3} \times \frac{5}{32}\ \text{mol acid} = 5\ \text{meq/m}^3\text{/day},$$

which is low compared with the amount of HCO_3' in the given example.

The addition of too much $CaCO_3$ to a pond seems to me to be only disadvantageous because of precipitation of phosphorus.

Hepher (1958) has given considerable attention to the problem of precipitation of $Ca_3(PO_4)_2$ and has given a useful diagram for calculation of the amounts of Ca and PO_4 that can exist together in a solution at different pH values. His experimental results sometimes agree with the calculated values. /Hepher used 1×10^{-25} as the solubility product of $Ca_3(PO_4)_2$ in his calculations, and mentioned still lower values. But even 1×10^{-25} is much lower than can be calculated from the solubility of $Ca_3(PO_4)_2$ (20 - 30 mg/l), which gives $10^{-20} - 10^{-21}$. This enormous difference may be caused by the fact that $Ca_3(PO_4)_2$ in water forms compounds such as hydroxyapatites or even their Cl' or F' salts. (See Remy, 1956, pp.624 and 638)/. However, the differences are too large to be neglected and in table 6 of his paper the possibility of precipitation of $3\ Ca_3(PO_4)_2 \cdot 2Ca(OH)_2$ or $Ca_5(PO_4)_3OH$ must be considered. (See section 5 below). It might have been interesting to know the chemical composition of the precipitates occurring in his experiments, as it can be concluded that Ca is precipitated in quantities largely exceeding those of the phosphate, which leads to the hypothesis that very complicated precipitates occurred.

Hepher (1958) certainly shows a correlation between $CaCO_3$ content of the mud and $Ca_2(PO_4)_3$ precipitation, but no proof of the proposed reaction between $CaCO_3$ and PO_4 ions. Barrett (1953) also supported the fact that the disappearance of added phosphorus from epilimnial water is related to alkalinity. Furthermore, Hepher's idea that no adsorption onto heavy metals can take place because of the high pH is not necessarily true. Ohle (1937-1938) indeed demonstrated that PO_4''' adsorbed onto $Fe(OH)_3$ could be washed out with $Ca(HCO_3)_2$ solutions. But in ion-exchange processes the continuous renewal of the solvent shifts the equilibrium $Fe(OH)_3 \sim P \rightleftarrows Fe(OH)_3 + H_3PO_4$ to the right, by permanently removing one of the reaction's products. Ohle's experiment only proved that adsorption of phosphate to $Fe(OH)_3$ is less at pH 8.6 than at pH 6.0.

Hepher also considers the possibility that phosphate is taken up by the algae in excess of their normal requirements. In my opinion the presence of polyphosphates in algae and the P uptake by bacteria are more important than Hepher thinks, as can be calculated by their rapid turnover times (for algae see for example Coffin, 1949). As the polyphosphates are beyond the scope of this paper, I only mention the papers of Baker (1964), Curnutt and Schmidt (1964) and Kuhl (1962).

4 SUMMARY OF 2 AND 3

The conclusion about the iron-sulphur-phosphorus and the calcium-carbonate-phosphorus system must be that it is not yet possible to know which type of sorption or precipitation is the main process in a given mud after the addition of phosphate.

It is extremely urgent to know more about the systems combined. It is desirable to start quantitative investigations with the $Ca-CO_3-PO_4$-system and the $F-S-PO_4$-system separately, and to combine both systems after we have learned to distinguish between $FePO_4$, $Fe(OH)_3$~P and $[Ca_3(PO_4)_2]$, whatever the composition of the last precipitate may be. The hypothesis (Neess, 1949) that the addition of lime before fertilization with phosphate will save the latter from precipitation in iron-phosphorus complexes, still seems very doubtful. For the study of the entire mud system radiophosphorus experiments and determinations of iron and calcium activities must be carried out simultaneously. Too little attention has been paid to the determination of organic phosphates, both dissolved and particulate, in fish ponds. Before any conclusions about the uptake of phosphorus by the mud are drawn, the turnover times of the phosphorus compounds during primary production must be measured. P^{32} combined with C^{14} may be used by all workers applying the C^{14} technique.

5 OTHER SORPTION PROCESSES ON COLLOIDS AND EXCHANGE PROCESSES

5.1 Iron-humus-phosphorus system and iron or aluminium-silicon-humus systems

Humic acids are supposed to form complexes with heavy metals, mostly Fe, by chelation (cf.EDTA).

However, as chelation leads only to an equilibrium, the iron linkage to the humic acids in dissolved state will always be counteracted by high calcium concentration. This difficulty is overcome by the finding of Shapiro (1964), who observed that dissolved iron, which in oxygenated water must be in the ferric form, is bound to particles (of yellow acids) larger than $0.5/\mu$, and he described some properties of such complexes. Shapiro believes that in highly coloured waters the large quantities of iron held in apparent solution are in the form of a protected colloid and that chelation plays a relatively minor role. The bound metal in its turn can combine with phosphorus compounds.

I could find in the literature no proof of the assumption that the calcium in lime can displace other fertilizing substances from organic colloidal systems (Neess, 1949), nor of the flocculation of the colloidal humus gels and the ability of these colloids to liberate hydrogen. As long as our knowledge of the structure of the humic acids is only hypothetical, one has to be very careful in proposing chemical mechanisms. Although there appears to be a close structural relationship between the organic matter present in lacustrine and marine sediments and the waters on one hand, and that present in soils on the other hand (see for example Povoledo, 1964), it is not safe to use data about adsorption from soil chemistry, as the equilibria in the aquatic system may differ from the discontinuous soil system.

Ohle (1955; 1964) has made some investigations on the adsorption to humic acids and demonstrated a linkage of phosphorus and silicon to iron and aluminium-humic acid complexes. The objection might be made that he used "Merck" humic acids. It is preferable, although more difficult, to use "native" humic acids, to avoid the risk of a change in sorption properties by purification.

Ryhänen (1964) also described aluminium-humic acid complexes. Ohle furthermore demonstrated a linkage of silicate to ferric and aluminium hydroxide. The question, whether iron- and aluminium silicates (as kaolinite $Al_2[Si_2O_5](OH)_4$ and montmorillonite $AlSi_2O_5(OH)$) with or without iron oxide behave as ion exchangers under natural conditions, remains to be proved.

5.2 Exchange processes

The same objection must be made to the supposition that minerals like apatite $3Ca_3(PO_4)_2 \cdot Ca(F,Cl)_2$, phosphorite $3Ca_3(PO_4)_2 \cdot Ca(OH)2$, vivianite $Fe_3(PO_4)_2 \cdot 8\ H_2O$ and wavellite $3Al_2O_3 \cdot 2P_2O_3 \cdot 12\ H_2O$ regulate the phosphorus concentration in the lake water. Whether the Ca of minerals in mud is exchangeable like the Ca in soil clay (see for example Borland and Reitemeier, 1950) must still be investigated.

In experiments with radiophosphorus always a rapid exchange between P^{31} and P^{32} can be found. This exchange which must be distinguished from adsorption processes, can give some information about the nature of phosphorus compounds present, but not about the quantity of phosphorus "stored" in mud. In literature a good distinction between the exchange process: $X\ P^{31}O_4 + P^{32}O_4 = X\ P^{32}O_4 + P^{31}O_4$ and the adsorption process: $X(Y)_3 + PO_4''' = X\ PO_4 + 3\ Y$ is not always made. Furthermore the fact must be mentioned that under conditions leading to the formation of phosphorite in nature, the product is not $Ca_3(PO_4)_2$ but hydroxylapatite $3Ca_3(PO_4)_2 \cdot Ca(OH)_2$ or $Ca_5(PO_4)_3(OH)$. This compound is also formed when tert. calciumphosphate is suspended in water (which compound therefore cannot be prepared in the pure state by precipitation from a solution), while even $CaHPO_4$ is decomposed by water by the reaction:

$$7\ CaHPO_4 + H_2O \longrightarrow Ca_5(PO_4)_3OH + 2\ Ca(H_2PO_4)_2$$

For further information see Remy, 1956: pages 624, 638.

Livingstone and Boykin (1962) studied the phosphorus in the sediment of Linsley Pond and suggested that a large quantity of the phosphate is bound to the mineral material below the gyttja, by sorption reactions. The mineral part was not present as apatite, as appeared from the solubility in acids. In their interesting discussion, they remark that high phosphorus binding capacity is correlated with high mineral content of lake mud. A comparison of the adsorption capacities of the gyttja and the mineral material as a function of the phosphorus concentration of the overlying water would have been very interesting.

Macpherson, Sinclair and Hayes (1958) studied the pH dependence of phosphate sorption by dried mud of different lakes and the ash of this mud. Both curves from eight lakes studied showed a maximum sorption at pH values 5 - 7, the ash giving off more phosphate than the dried mud when shaken with distilled water. The organic part of mud appeared to moderate the phosphate release at the end of the pH range. Both facts were confirmed by shaking the mud with one ppm of phosphate. However, it may not be concluded from their figures whether they measured a pH effect (a sorption reaction) or an effect by changing the ionic strength (an exchange reaction). The activity of the ash compared with the mud as a whole may also be an activation effect by heating. Furthermore they found a similarity of the pH effect on lake mud ash, to the effects on betonite, fuller's earth and ferric hydroxide as described in the literature.

The distribution of P^{32} between mud and water was studied by Hayes and Phillips (1958), who found in the first place that in natural Jenkin sampler cores, in artificial cores and in bottles in which dredged surface mud was packed by centrifuge, the phosphorus equilibration pattern and rate were the same, which proved that layering was relatively unimportant. Furthermore they found that in the presence of bacteria the amount of P^{32} remaining in the water at equilibrium was greater than where antibiotic had been added. Beside the two explanations Hayes and Phillips have given, it is also possible - considering the chemical formulae of their antibiotics - to propose the hypothesis that the antibiotics themselves influenced the sorption system.

They found turnover times to be: for bacteria or phytoplankton ± five minutes, confirming the results of Coffin (1949), for the water of the whole lake one week, for mud in a bottle half a week (without bacteria two weeks), and for lake sediments in nature (including rooted aquatics) one month. Zooplankton was unable to use phosphorus until bacteria had made it organic; its turnover time was then one day.

Pomeroy (1965) studied the phosphorus exchange of P^{32} with cores and suspended sediments containing as principal clay minerals kaolinite and montmorillonite. They found a two-step ion exchange between the clay minerals and the phosphate of water, plus an exchange between micro-organisms and water. The latter appeared to be trivial in undisturbed sediments but to equal the inorganic process in suspended sediments. They do not mention whether the sediments contained calcium carbonate or calcium phosphate precipitates.

Although findings may vary from lake to lake, these results may be of great help in a clearer understanding of the phosphorus balance in fish ponds.

Radiophosphorus experiments in lake sediments were carried out by Olsen (1958; 1964), who made the right distinction between exchange and adsorption, but whose paper did not receive the attention it deserved. Olsen used a coarse sediment from 3 metres and a finely grained deep water sediment, both in reduced as well as oxidized state. He found that the relations between the phosphorus in the water and that in the sediment could be described by the same mathematical formula, with reservation in respect to the phosphate release from the reduced sediments, the relation being a hyperbola-like function of the form

$$b = K_b \cdot C^{-V_b}$$

in which b is the exchange phosphorus in γ's P per g dry matter while K_b and V_b are constants and C is the concentration in the solution in γ's P per ml.

Addition of this exchange quantity to the net adsorbed quantity (a) gives the gross adsorbed quantity (A), which Olsen described by the Freundlich adsorption isotherm

$$A = K.C^V$$

The full mathematical description of the direct measurable net adsorbed quantity was calculated by Olsen as

$$a = A - b = K.\,C^V - K_b\,.C^{-V_b}$$

It is shown by Olsen that the exchange of the phosphorus is a very rapid process and that uptake of phosphorus from water by algae will be followed by a release of phosphorus from the sediments, with different constants for oxidized or reduced sediments. In the oxidized state sediment exchanges and adsorbs more phosphorus than in the reduced state, which is another argument for investigating the extent of reduction of fish pond bottoms. In the reduced state the sediment from deeper water showed no adsorption of phosphorus - and therefore only release - when the concentration of phosphorus was below 2 mg P/l, which is a high value.

It would be interesting to know whether the divergent fate of phosphorus in reduced "deep" sediments is related to redox-potentials and iron metabolism. It can be imagined that the reduced "deep" sediment has lost all its active iron and that the adsorption of phosphorus from solutions containing more than 2 mg P/l takes place by a different process, for example precipitation with calcium.

6 POTASSIUM

Schäperclaus mentioned in his review that K is adsorbed to the mud during winter and released during summer. He quotes a study of Breest (1924) as the only source of this information. Neess (1949) again quotes Breest about evidence for K exchange between mud and water. Breest's paper, however, does not give the information that Schäperclaus and Neess report. In the first place Breest did not measure potassium sorption but sorption of Cl'ions which need not be the same as K sorption. Doubtless mud contains a large reservoir of potassium, but as the K-ion has only one electrovalence and KCl in a solution is completely ionized, the binding of the K to the mud leaves the Cl'ion in the water. Moreover his paper, dealing also with the flocculation of colloids, lacks technical information, for example about the influence of time on his results.

Edwards and Rolley (1965) studied the exchange between interstitial water and water overlying mud deposits. From their figures it appears that no adsorption of Li takes place. When the K linkage to the mud follows an ion exchange pattern it seems likely that lithium, too, should have been adsorbed. Their experiments, therefore, give "circumstantial evidence", but no proof, of a non-ionic nature of the linkage.

Wiklander (1950) wanted to remove K from a micaceous clay and needed therefore 21 days of treatment with N solutions of HCl, NaCl, NH_4Cl or $CaCl_2$ at a temperature of 65 to 70°C. Although this clay came from soil, this fact shows that the K fixed in minerals is not always easily exchangeable.

7 NITROGEN

The role of nitrogen in fish ponds has been reviewed by Hepher (1952b) and Neess (1949). There is no general answer to the question whether N-manuring is necessary because the ponds are so very different. However, the fact must be stressed that elimination of one limiting factor (e.g. phosphorus) automatically causes a second factor to become limiting (probably nitrogen, sometimes perhaps silicon or iron).

For a good growth of algae the quantities of nitrogen and phosphorus (in mg) should be available in a ratio varying from 10:1 to 4:1, because the same ratio normally occurs within the algae. (When polyphosphates are stocked in the algae, the lower ratio will be approached).

By determining the turnover time of phosphorus in the algae, the amount of nitrogen required can be estimated. However, only part of this amount has to be generated by mud, as nitrogen is rapidly remineralized after the death of the algae (Golterman, 1960). In our laboratory experiments we found that after three to five days, 50 - 75 percent of the incorporated nitrogen is mineralized to ammonia by bacteria. As the sinking rate of plankton is in the order of magnitude of one metre a day in stagnant water, it is most likely that in fish ponds which are shallow and strongly influenced by wind the algae will probably be broken down before they reach the mud. In an experimental plastic pond without mud at the bottom we found a 100 percent mineralization in two to three days after a bloom of Chlamydomonas had died off. Ohle (1962) has also described a 90 percent mineralization of the incorporated nitrogen, in the upper layer of a lake, in a few weeks. During this process the algal material is converted to ammonia and CO_2, bacterial substance and soluble organic substances. The ratio of the products formed is determined by the C/N ratio of the plankton, which can be estimated as about $C_5H_7NO_2$ (Busch, 1965). The remaining, not easily mineralizing compounds must be broken down in the mud, probably also by bacteria. A study of this process was made by Fair, Moore and Thomas (1941b), whose work on O_2 uptake will be discussed later. They found that the quantities of soluble nitrogen products formed are determined by physical conditions of environment, relative activity of fermentation, and variations in the initial concentrations and constitution of nitrogenous matter in the deposits. During their experiments (differing in time from 145-450 days) one quarter to three quarters of the total nitrogen in the mud was observed to remain in the deposits. Schäperclaus thinks that a neutral mud stimulates this process (an argument in favour of Ca - manuring) but this theory lacks experimental proof. Very little is known of the factors stimulating the mineralization process.

An important factor to determine which substances are released is the redox potential. Kusnetzow and Musnetzowa (1935), (see Mortimer, 1942, p. 199) found for example that the reduction of formic acid to methane took place most actively in mud at a redox potential of $E_7 = -0.12$ V., with C and N supply as the controlling factors.

There are two more processes by which mud can influence the N cycle:

(i) Adsorption of NH_4^+ to the colloidal parts. No experimental proof of this process is found in the literature.

(ii) Reduction of nitrate to ammonia. Mortimer (1941) has found that below a redox potential of $E_7 = +0.35$ V. only ammonia can be detected (this potential was associated in his work with an oxygen concentration of 0.4 mg/l).

Owens and Edwards (1963) have shown that mud, even when the overlying water contains O_2, reduces nitrate, principally to nitrogen or ammonia. The nitrate acts as an alternative hydrogen acceptor to the oxygen. Edwards and Rolley (1965) found that nitrate reduction by mud is high when either the O_2 consumption by the mud or the nitrate concentration in the water is high.

From their findings it may be concluded that in fish ponds, where a high NO_3' concentration is desirable, the nitrate will easily be reduced to ammonia when the mud has a high O_2 consumption, probably causing a harmful effect on the fish.

8 SILICON

If any exchange processes of silicon compounds take place in the mud, they must have the character of ion exchange processes. It has been found that the silicates in the hypolimnion of stratified lakes is constantly increasing. It is not known whether this increase is directly influenced by the fall of the redox potential. Of course silicates themselves cannot be reduced, but it might be interesting to find out whether the rise in iron or calcium concentration leads to a higher silicate concentration in the water. The nature of the silicon compounds in the water is not yet known, nor do we know which compounds are determined by the normal silicon-molybdate complex reagent.

Part of the silicon in the water originates from dead diatoms. This mineralization is a non-enzymatic slow process. Jørgensen (1955) found for example that for Nitzschia linearis at pH = 10 a maximal amount of 20 percent of the silicon dissolved after 85 days, whereas at the same pH for Thalassiosira nana this amounted to 97 percent after 37 days. These differences may be explained by the assumption that there exists "functional" and "stored" silicon, with different mineralization times (Golterman, 1960). We found that the mineralization of the silicon of Stephanodiscus hantzschii depends on the bicarbonate concentration of the suspending medium and on the concentration of the dissolved silicate.

9 OXYGEN UPTAKE

Mud always takes up oxygen for chemical and bacteriological decomposition processes. By the addition of poisons like $HgCl_2$ or toluene a distinction between these processes can be made, but this has probably no practical significance for fish ponds. The extent of the uptake, however, strongly influences the O_2 concentration in the water and thereby many redox reactions. The measuring technique of Knowles, Edwards and Briggs (1962) appears to be suitable even when no sophisticated laboratory is available. Edwards recently measured an uptake of 0.1 and 0.2 g $O_2/m^2/h$, which means 2.4 - 4.8 $g/m^2/day$. When a water layer of one m is assumed, this means that 50 percent of the dissolved O_2 is consumed by the mud. They found no significant change in O_2 consumption with mud depth ranging between 4 and 17 cm, contrary to the findings of Fair, Moore and Thomas (1941 a,b,c) and Baity (1938). The latter found that the relation between O_2 demand (Y) and sludge depth (X) is

$$Y = 2700\ X^{0.485}$$

Probably in each case the composition of the mud and also the accumulation time were different.

Edwards (1958) stressed the importance of invertebrates in affecting the physical, chemical and microbiological conditions within the deposits when the benthal O_2 demands are measured.

Fair, Moore and Thomas (1941 a,b,c) studied some other factors influencing the O_2 uptake of river mud and have given some mathematical formulae concerning the effect of temperature. Furthermore they studied (1941 a and c) the decrease of the potential oxygen demand of the decomposable matter, caused by anaerobic decomposition. This decomposition gains in importance when the sediments grow in depth, although the aerobic processes remain the most important quantitatively. Although their work on river muds is connected with sewage and sludge purification we must keep in mind that comparable processes are bound to occur at the bottom of the always very eutrophic fish ponds.

10 REFERENCES

Armstrong, F.A.J. and H.W. Harvey, The cycle of phosphorus in the waters of the English Channel. J.Mar.biol.Ass.N.S., 29:145-62
1951

Baity, H.G., Some factors affecting the aerobic decomposition of sewage sludge deposits. Sewage Works J., 10:539-68
1938

Baker, A.L., Polyphosphate metabolism during nuclear division in synchronous growing Chlorella. Biochim.biophys.Acta, 82(3):624
1964

Barret, P.H., Relationships between alkanity and adsorption and regeneration of added phosphorus in fertilized trout lakes. Trans.Amer.Fish.Soc., 82:78-90
1953

Borland, J.W. and R.F. Reitemeier, Kinetic exchange studies on clays with radioactive calcium. Soil Sci., 69:251-60
1950

Breest, F., Uber die Beziehungen zwischen Teichwasser, Teichschlamm und Teichuntergrund. Arch.Hydrobiol., 15:422
1924

Busch, A.W., Determination of biologically degradable carbon concentration in water. Hydrobiologia, 26(1-2):128-9
1965
Symposium on new methods of determining biogenic and organic substances in water and organisms; held in 1963 in Zivohošt, Czechoslovakia.

Coffin, C.C. et al., Exchange of materials in a lake as studied by the addition of radioactive phosphorus. Canad.J.Res.(D), 27:207-22
1949

Curnutt, S.G. and R.R. Schmidt, Possible mechanisms controlling the intracellular level of the inorganic polyphosphate during synchronous growth of Chlorella pyrenoidosa. Biochim.biophys.Acta, 86(1):201
1964

Dussart, B., Limnologie; l'étude des eaux continentales. Paris, Gauthiers-Villars, 618 p.
1966

Edwards, R.W., The effect of larvae of *Chironomus riparius* Meigen on the redox potentials
1958 of settled activated sludge. *Ann.appl.Biol.*, 46(3):457-64

Edwards, R.W. and H.L.J. Rolley, Oxygen consumption of river muds. *J.Ecol.*, 53(1):1-19
1965

Einsele, W., Uber die Beziehungen des Eisenkreislaufs zum Phosphatkreislauf im eutrophen
1936 See. *Arch.Hydrobiol.*, 29:664-86

__________, Physikalisch-chemische Betrachtung einiger Probleme des limnischen Mangan-
1937 und Eisenkreislaufs. *Verh.int.Ver.Limnol.*, 5(3):69-84

__________, Uber chemische und kolloidchemische Vorgänge in Eisen-Phosphat Systemen
1938 unter limnochemischen und limnogeologischen Gesichtspunkten. *Arch.Hydrobiol.*, 33:361-87

Fair, G.M., E.W. Moore and H.A. Thomas, The natural purification of river muds and pollu-
1941a tional sediments. *Sewage Works J.*, 13(2):270-307

__________, The natural purification of river muds and pollutional sediments. *Sewage*
1941b *Works J.*, 13(4):756-79

__________, The natural purification of river muds and pollutional sediments. *Sewage*
1941c *Works J.*, 13(6):1209-28

Fogg, G.E., Glycollic acid as an extracellular product of phytoplankton. *Chem.Weekblad*,
1964 60(38):515-9

Fogg, G.E. and C. Nalewajko, Experiments concerning the extent of liberation of extra-
1963 cellular products by plankton algae. *Proc.roy.Soc.(B)*, 157:381-2

Golterman, H.L., Studies on the cycle of elements in fresh water. *Acta bot.neerl.*, 9:
1960 1-58

__________, Mineralization of algae under sterile conditions or by bacterial breakdown.
1964 *Verh.int.Ver.Limnol.*, 15:544-8

__________, *Mitt.int.Ver.Limnol.*, 14 (in press)

Gorham, E., Observations on the formation and breakdown of the oxidized microzone at the
1958 mud surface in lakes. *Limnol.Oceanogr.*, 3(3):291-8

Gorham, E. and D.J. Swaine, The influence of oxidizing and reducing conditons upon the
1965 distribution of some elements in lake sediments. *Limnol.Oceanogr.*, 10(2):268-79

Hayes, F.R. and J.E. Phillips, Lake water and sediment. 4. Radiophosphorus equilibrium
1958 with mud, plants and bacteria under oxidized and reduced conditions. *Limnol.Oceanogr.*, 3(4):459-75

Hayes, F.R., B.L. Reid and M.L. Cameron, Lake water and sediment. 2. Oxidation-reduction
1958 relations at the mud-water interface. *Limnol.Oceanogr.*, 3(3):308-17

Hayes, F.R. *et al.*, On the kinetics of P exchange in lakes. *J.Ecol.*, 40:202
1952

Hellebust, J.A., Excretion of some organic compounds by marine phytoplankton. Limnol.
1965 Oceanogr., 10(2):192-206

Hepher, B., The fertilization of fish ponds. 1. Phosphates. Bamidgeh, 4(718):131-4
1952a

__________, The fertilization of fish ponds. 2. Nitrogen. Bamidgeh, 4(10/11/12):
1952b 220-3

__________, The fertilization of fish ponds. 3. Organic Matter. Bamidgeh, 5(1/2):
1953 19-24

__________, On the dynamics of phosphorus added to fish ponds in Israel. Limnol.
1958 Oceanogr., 3:84-100

Jørgensen, E.G., Solubility of the silica in diatoms. Physiol.Plant., 8:846-51
1955

Kanai, R., Sh. Miyachi and Shigetoh Miyachi, Light-induced formation and mobilization
1963 of polyphosphate "C" in Chlorella cells. In Studies on microalgae and photosynthetic bacteria, ed. by Japanese Society of Plant Physiologists, Tokyo, pp. 613-8

Knowles, G., R.W. Edwards and R. Briggs, Polarographic measurement of the rate of respiration of natural sediments. Limnol.Oceanogr., 7(4):481-3
1962

Kuhl, A., Inorganic phosphorus uptake and metabolism. 5. Condensed inorganic phosphates. In Physiology and biochemistry of algae ed. by R.A. Lewin, New York, Academic Press, pp. 218-29
1962

Kusnezow, S.I. and Z.I. Kusnezowa, Die bakteriologische und die chemische Untersuchung
1935 von Seeschlammen im Zusammenhang mit der Gasausscheidung aus dem Seegrund. Trudy Limnol.Sta.Kosíne, 19:127-44 (Only in Russian)

Lewis, G.C., G.O. Baker and R.S. Synder, Phosphate fixation in calcareous soils.
1950 Soil Sci., 69:55-62

Livingstone, D.A. and J.C. Boykin, Vertical distribution of phosphorus in Linsley Pond
1962 mud. Limnol.Oceanogr., 7(1):57-62

Maciolek, A., Artificial fertilization of lakes and ponds. Spec.sci.Rep.U.S.Fish
1954 Wildl.Serv.-Fish., (113)

Macpherson, L.B., N.R. Sinclair and F.R. Hayes, Lake water and sediments. 3. The
1958 effect of pH on the partition of inorganic phosphates between water and oxidized mud or its ash. Limnol.Oceanogr., 3(3):318-26

Mortimer, C.H., The exchange of dissolved substances between mud and water in lakes.
1941 J.Ecol., 29:280-329

__________, The exchange of dissolved substances between mud and water in lakes.
1942 J.Ecol., 30:147-201

__________, Underwater "soils"; A review of lake sediments. J.Soil Sci., 1:63-73
1950

Mortimer, C.H. and C.H. Hickling, Fertilizers in fish ponds. Fish.Publ.,Lond., (5):
1954 155 p.

Nalewajko, C., N. Chowdhuri and G.E. Fogg, Excretion of glycollic acid and the growth of
1963 a planktonic *Chlorella*. Microalgae a.Photosynthetic Bact., 171-83

Neess, J.C., Development and status of pond fertilization in Central Europe. *Trans.*
1949 *Amer.Fish.Soc.*, 76:335-58

Ohle, W., Kolloidgele als Nährstoffregulatoren der Gewässer. *Naturwissenschaften*, 25
1937 (29):471-4

__________, Die Bedeutung der Austauschvorgänge zwischen Schlamm und Wasser für den
1938 Stoffkreislauf der Gewässer. *Vom Wasser*, 13:87-97

__________, Ionenaustausch der Gewässersedimente. *Mem.Ist.ital.Idrobiol.*, Suppl.(8):
1955 221-45

__________, Der Stoffhaushalt der Seen als Grundlage einer allgemeinen Stoffwechsel-
1962 dynamik der Gewässer. *Kieler Meeresforsch.*, 18(3):107-20

__________, Kolloidkomplexe als Kationen- und Anionenaustauscher in Binnengewässern.
1964 *Vom Wasser*, 30:50-64

Olsen, S., Phosphate adsorption and isotopic exchange in lake muds; experiments with
1958 P 32. Preliminary rep. *Verh.int.Ver.Limnol.*, 13:915-22

__________, Phosphate equilibrium between reduced sediments and water: Laboratory
1964 experiments with radioactive phosphorus. *Verh.int.Ver.Limnol.*, 15:333-41

Owens, M. and R.W. Edwards, Oxygen studies. *Proc.Soc.Wat.Treatm.Exam.*, 12:126-45
1963

Pearsall, W.H. and C.H. Mortimer, Oxidation-reduction potentials in waterlogged soils,
1939 natural waters and muds. *J.Ecol.*, 27:483-501

Perkins, A., Phosphate solubility in relation to cations and pH: Magnesium. *Proc.Soil Sci.*
1947 *Soc.Amer.*, 12:185-7

Pomeroy, L.R., E.E. Smith and C.M. Grant, The exchange of phosphate between estuarine
1965 water and sediments. *Limnol.Oceanogr.*, 10(2):167-72

Povoledo, D., Some comparative, physical and chemical studies on soil and lacutrine
1964 organic matter. *Mem.Ist.ital.Idrobiol.*, 17:21-32

Remy, A., Treatise on inorganic chemistry. 1. Amsterdam, London, Elsevier P., pp.
1956 624-5,638

Ryhänen, R., Beobachtungen über "Humuskolloide" in angewandter Limnologie. *Verh.int.*
1964 *Ver.Limnol.*, 15:276-83

Schäperclaus, W., Lehrbuch der Teichwirtschaft; zweite erw.Auflage. Berlin u. Hamburg,
1961 P.Parey, 582 p.

Shapiro, J., Effects of yellow organic acids on iron and other metals in water. *J.Amer.*
1964 *Wat.Wks.Ass.*, 56(8):1062-82

Sorokin, Yu. I., Proceedings of the Symposium, in Pallanza, on the Primary Productivity
1966 measurements *Mem.Ist.ital.Idrobiol.*, 18(Suppl.):187-205

Wiklander, L., Fixation of potassium by clays saturated with different cations. *Soil*
1950 *Sci.*, 69:261-80

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FERTILIZATION IN WARM-WATER POND FISH CULTURE IN AFRICA

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FERTILIZATION IN WARM-WATER POND FISH CULTURE IN AFRICA

Abstract

Experience in the use and effects of fertilizers in Africa is summarized and the views of workers on the value of different fertilizing methods and their role in fish culture examined. Organic fertilizers appear to be widely used but in some areas much use has been made of inorganic compounds, mainly phosphates with lime as a "conditioner". The need for critical work on the biology and chemistry of fertilized water is stressed as is the importance of a background knowledge of waters and water chemistry in order to understand the role of fertilizers. There appears to be conflicting evidence on the value of inorganic fertilizers but it has an important role particularly in *Tilapia* culture and where costs of foodstuffs are high.

L'UTILISATION D'ENGRAIS DANS LA PISCICULTURE EN ETANG A TEMPERATURE ELEVEE EN AFRIQUE

Résumé

Cette communication résume les expériences menées en Afrique sur l'utilisation et l'effet des engrais et passe en revue les opinions des chercheurs sur la valeur des différentes méthodes de fertilisation et leur rôle dans la pisciculture. L'emploi des engrais organiques paraît être largement répandu mais, dans certaines régions, il a été fait un grand usage de composés inorganiques, notamment de phosphates associés à de la chaux servant d' "amendement". L'auteur insiste sur la nécessité d'entreprendre des travaux critiques sur la biologie et la chimie des eaux fertilisées et souligne que le rôle des engrais ne sauraient être compris sans une connaissance générale des eaux et de la chimie des eaux. Il semble y avoir des témoignages divergents quant à la valeur des engrais inorganiques mais ces éléments jouent un rôle important, notamment dans l'élevage des *Tilapia* et là où les produits alimentaires coûtent cher.

FERTILIZACION DE LOS ESTANQUES DE AGUA TEMPLADA EN AFRICA

Extracto

Se hace un resumen de los resultados del empleo y efecto de los fertilizantes en Africa y se examinan las opiniones de los investigadores sobre el valor de los diferentes métodos de fertilización y su función en la piscicultura. Los fertilizantes orgánicos se utilizan ampliamente, pero en algunas zonas se ha recurrido también a los compuestos inorgánicos principalmente fosfatos con cal como "acondicionador". Se hace resaltar la necesidad de un trabajo crítico sobre la biología y química de las aguas fertilizadas, así como la importancia de un conocimiento básico de las mismas y de la química acuática, con el fin de comprender la función de los fertilizantes. Parecen ser contradictorias las pruebas sobre el valor de los fertilizantes inorgánicos, pero éstos tienen un papel importante, particularmente en el cultivo de *Tilapia* y en los casos en que los costos de los productos destinados a la alimentación son elevados.

1 INTRODUCTION

Natural fresh-water fisheries have long been important in Africa, but the cultivation of fish in ponds is a recent innovation. Tilapia species, which are the most commonly used pond fish in Africa, were apparently first tried in ponds in Kenya, in the nineteen twenties (Copley, 1952), although carp (Cyprinus carpio) had been tried in South Africa in 1859 and in Madagascar in 1914 (Bard, 1962). Fish culture was also started before the second world war in the then Belgian Congo, but it was not until after this war that fish culture was seriously investigated in Africa.

This review deals with methods of pond fertilization suggested in reports and publications in tropical and south Africa and Madagascar; though very few investigations have been made on a statistical and scientific basis. Little critical work has been carried out on the effects of fertilizers on the biological cycle of ponds in Africa. Much reliance has been placed on work in Europe, America and the Far East. The careful studies recently carried out at the Malacca Tropical Fish Culture Research Institute should help to stimulate the much needed critical scientific work in Africa.

In Africa much basic and background knowledge is required before fertilizers can be used to best advantage. Studies by Van Someren and Whitehead (1959) in Kenya have provided some basis for understanding the biology of Tilapia in unfed and unfertilized ponds; Le Roux (1955) in South Africa carried out tank experiments to follow chemical and biological changes following fertilization with poultry manure, and Depasse (1956) has considered water quality. Hey (1952) and observations at Fisheries Research Centre Rhodesia (unpublished) stress the role of soils and pond mud. In Africa there are great differences between one area and another; conflicting results in various reports may in many cases be traced to differences in soil and water types, and definite results on fertilizer use under varying conditions are not yet available.

The economic and social environment for most African fish culture suggests use of small domestic ponds of one to two acres, so feeding utilizing cheap wastes, and the use of organic manure,have been stressed, rather than fertilizer use. The value of inorganic fertilizers is appreciated, but these are generally too highly priced for general use in most parts of Africa. However this situation may change (Bard, 1962), and Mortimer (1962) points out clearly the monetary advantage to be obtained when foodstuffs are even moderately expensive and fertilizers are obtainable; taking natural production as unity, the profit index is two with artificial food,7.5 with fertilizer.

Capart and Kufferath (1957) point out that algae are generally more efficient primary producers than higher plants and that energetically it is more efficient to produce food in the pond through chemical elements added or by bacterial transformation of organic material; they propose a scheme of investigations to relate potential production, as calculated by biochemical means, to the real production, and so help to answer the question how best to obtain maximum yield at minimum cost.

It is clear from the published work that the importance of critical work and the role of fertilizers are appreciated,but very little of the basic investigations have yet been made in Africa, and fertilizers are not yet widely used.

The existing information on the use of different types of fertilizers in the various parts of Africa is briefly reviewed below.

2 LIME

2.1 South Africa

South African workers find the use of lime valuable. Hey (1952) gives recommendations based on European fish culture for soils of differing pH and types and points out that the application of mineral fertilizers may have little or no effect in waters deficient in calcium as judged by their alkaline reserve. He cautions against the sudden change of soil pH which may render the pond bottom sterile until the existing organisms are replaced by forms preferring alkaline medium. The incorporation of superphosphates of lime in organic manure is recommended and following American workers ground limestone is used in inorganic mixtures. Van Schoor (1959) has confirmed in the same area that lime as $Ca\ Co_3$ has a negative effect on plankton production as shown by American workers, and he studied the effect of nitrogenous fertilizers with a neutral effect such as limestone and ammonium nitrate. His results are somewhat inconclusive since the experimental ponds leaked badly, but in general a rise in alkaline reserve was found.

Lombard (1959) in a useful practical handbook on fish farming in the Transvaal recommends the use of agricultural lime at a rate of 900 kg per hectare (800 lb per acre), spread on the dry pond bottom and ploughed in lightly. He also mentions the use of quicklime as a disinfectant at rates of 450 kg/ha (400 lb per acre) but this practice does not seem to be widespread.

2.2 Rhodesia and Zambia

Maar (1956) in Rhodesia recommends between 360-1,120 kg/ha (300-1,000 lb per acre) as a suitable application prior to the use of fertilizers. Mortimer (1961) suggests 1,675 kg/ha (1,500 lb) spread on the water at monthly intervals for ponds with soft water.

2.3 Tropical Africa

The use of lime is also recommended in early work in Uganda by Simpson (1955) as an improvement for acid water and (1956) in order to reduce turbidity of water on clay soils. No quantities are mentioned. Lime is used in routine practice in carp culture in Nigeria, Anon (1957).

Bonemeal treated with sulphuric acid would provide calcium and phosphates and de Bont (1950) mentions that in combination with maize sweeping (500 kg per hectare) gave excellent results as judged by turbidity and plankton response. Other Belgian workers agree as to the value of this. Huet (1957) mentions the value of lime since many waters in the Congo are poor in calcium, but points out that cost is a negative factor. Gruber (1960) suggests the use of wood ash at rates of some 3,000 kg/ha which would have a decided effect on alkalinity.

Charpy (1956) presents evidence showing the unimportant role of water chemistry and points out that the productivity of water with a high lime content is not very different from that of water with low lime content. He also mentions that liming gave disappointing results.

2.4 Madagascar

In Madagascar, Kiener (1956; 1957) obtained excellent results following the use of phosphate fertilizer containing 45 percent Ca O; he also suggests that liming at drainage will be useful for improving the muddy bottom of ponds.

According to FAO/UN (1961) quoted by Bard (1962), excess mud on the pond bottom is useless if not positively dangerous and that the mineralization of the mud by the application of lime permits an increase in the nitrate and phosphate content. As has been shown, the value of liming may be through a variety of interactions, lessening turbidity, releasing materials and increasing the calcium content. High applications do not seem to be required after initial dosage, but moderate quantities may well serve in the capacity of conditioner. The many sided effects are pointed out by Lombard (1959) who discusses the effects and uses of lime. In general the continuous use of lime on soils rendered neutral is probably at best unnecessary and at worst detrimental. Moderate quantities as a hygienic measure on muddy bottoms and where organic manure has been used is in most cases beneficial.

3 INORGANIC FERTILIZERS

There are numerous reports on the use of various inorganic fertilizers, mainly phosphatic and nitrogenous, but none on critical experiments to determine optimum levels and the exact chemical consequences. Frequency of application is discussed but here again most conclusions seem to be very much rule of thumb. De Bont (1956) in an annual report quotes work by Maes which discusses the background to inorganic fertilizing. He mentions that phosphate applied may be lost by precipitation as calcium phosphate or iron phosphate in waters rich in calcium and iron. How does one determine whether phosphates, for instance, form a limiting factor, asks Maes and suggests in answer that a determination of dissolved salts' variation with time, in relation to plankton concentration is the best method, those elements decreasing markedly at plankton increases being the most likely limiting factors. Maes makes a good case for the use of inorganic fertilizers, because of their high concentration of nutrient salts, in combination with organic manures which ensure a sufficiency of carbon dioxide.

3.1 South Africa

In South Africa Hey (1952) suggested similar recommendations as American workers. Although inorganic manures are more costly he suggests that the labour involved in the preparation of organic manures renders them less attractive. Combinations of nitrogen, phosphorus and potash in a 1:2:1 mixture gave good results in the Cape Province when made up as follows:

18 kg ammonium sulphate or 27 kg sodium nitrate,
27 kg superphosphate of lime,
2.3 kg muriate of potash, and
7 kg ground limestone.

This was applied at 224 kg/ha as an initial dose and thereafter at approximately monthly intervals to maintain a green brown colour and transparency of less than 30 cm.

van Schoor (1959 and *in litt.*) carried out some interesting work on inorganic fertilizer in glass jars and small ponds, basing his doses originally on American work. This author discusses the value of urea, calcium ammonium nitrate, ammonium nitrate and ammonium sulphate with the addition of agricultural lime. He finds no benefit from the addition of potash which he feels is of value only as a trace element. In slightly acid to neutral waters he has developed a satisfactory mixture which is applied weekly during the warmer months only (due to the temperate climate at the Cape of Good Hope). This is 5 kg urea, 14 kg 19 percent superphosphate and 86.5 kg fowl manure per week per hectare. He suggests that in alkaline water 11.2 kg/ha of ammonium sulphate replaces urea.

Lombard (1960) states that in the Transvaal as much as four times the natural yield is obtained using lime and phosphatic fertilizers and that the production by this method is comparable with production in which fish are artificially fed. He used annual applications of 185 kg/ha of 19 percent superphosphate or 225 kg per hectare of basic slag which contains trace elements. Basic slag is usually more effective in acid water, although this seems to be the most effective phosphatic fertilizer in an experimental fish farm in Nigeria where the water is generally alkaline (Anon, 1963). Lombard (*in litt.*) mentions that in the first year in *Tilapia mossambica* ponds agricultural lime and superphosphate increased the yield 4.4 times with a maximum of 600 kg per ha at a stocking rate of 42,000 fish per ha (17,500 per acre). In carp ponds the yield was increased 3.5 times to 264 kg per ha. This author mentions that one disadvantage of fertilizers is their stimulating effect on weeds in farm ponds.

In Natal using Tilapia melanopleura Crass (in litt.) applied 330 kg/ha 19 percent superphosphate and obtained over a five month period increases of 240 kg/ha of fish, over natural production.

3.2 Rhodesia

Maar (1956) makes recommendations for the fertilization of dams or farm ponds - small to large water storage reservoirs - in Rhodesia but points out that quantities required will vary with locality. He recommends N:P:K at 8:8:4 at approximately 220 kg/ha as an initial application and thereafter as required, (similar to Hey's recommendations). In soft waters sodium nitrate is to be used and in hard waters ammonium sulphate, in making this mixture. One to five applications per year may be required. In older dams superphosphate only is required. This author mentions that fertilizer should only be applied in shallow water less than five m (many of these ponds are deeper than this and stratify in summer for limited periods) and in weed free waters.

Application of 19 percent superphosphate in experimental ponds in Rhodesia consistently gave total production of 1,700 kg/ha and net productions of 1,100 kg/ha using mixed tilapia stocking. Nitrogen tended to show a depressing effect on yields of carp in artificially fed ponds at the Fisheries Research Centre in Rhodesia.

3.3 Zambia

In the 1950s Sklower (1951) while admitting the lack of experiments on fertilizer use in N. Rhodesia suggested the use of single superphosphate at rates of 150 kg/ha for a quick reaction or of rock phosphate, usually only necessary after the first year of operation.

Mortimer (in litt.) has some interesting observations on the method of application in relation to persistence of dissolved phosphorus. Using granular double superphosphate (30 percent) spread on the surface, fertilizer in floating perforated cannisters and in solution he found that while all showed a decrease in time the drop is remarkably less rapid in the water which received the solution and that the concentration after four weeks was considerably higher than with the other methods. Floating cannisters gave better results than conventional application by spreading. Unpublished results in Rhodesia where phosphate fertilizer was applied in hanging sacks in the water showed a greater response in plankton production, support this finding. Mortimer (1962) used applications of 55 kg/ha of double granular phosphate per month and obtained encouraging results in softer waters.

3.4 Uganda

In Uganda Simpson (1956) mentions that the addition of ammonium sulphate causes light but transitory blooms of phytoplankton. Previously (1953) the addition of phosphate and sulphates was recommended for increasing yield from ponds. Wurtz in his report on fish culture (FAO/UN, 1961) recommends the addition of phosphate after liming, particularly in carp culture. However, the Chief Fisheries Officer of Uganda reports (in litt.) that Pruginin working in Uganda on carp 1962-65 found no positive results on carp yield and growth due to phosphate and nitrogen fertilization.

3.5 Central Africa

De Bont (1952) mentions the use of phosphates as fertilizer and suggests that only small quantities should be used at a time to avoid excessive plankton blooms. In some industrial fish cultures near Elizabethville, phosphate fertilizers were used in addition to organic manure. Huet (1957) in his valuable survey of ten years of fish culture in the previous Belgian Congo suggests that applications of 150-200 kg/ha of phosphate fertilizer can be very valuable.

3.6 Madagascar

Kiener working in Madagascar finds the addition of 2,000 kg/ha of a compound containing 25 percent P_2O_5 useful in association with organic manure (1956; 1957).

3.7 Nigeria

Nigerian fish culture in ponds is stated to be still in the investigational stage (Niven *in litt.*), but nevertheless some results are available from this area. Carp appears to be the fish of most importance and on an experimental farm on the Jos plateau (Anon., 1963) 36 kg/ha of basic slag is applied at monthly intervals as a standard procedure. At normal stocking rates of 500 fish/ha phosphate alone at 1.15 tons/ha gave no advantage. At 1,000 fish/ha some advantage was found while again at 1,500 fish/ha there appeared to be no advantage.

The most noticeable effects would appear to be in soft water ponds and in the absence of feeding. Clearly there is much to be done in assessing rates and methods of application under different conditions.

4 ORGANIC FERTILIZERS, ANIMAL MANURES AND FOODSTUFFS AS FERTILIZER

The use of organic manures and the combination of animal rearing with fish culture is widespread. Cautions against excessive use and the limitations of organic manures are voiced by a number of workers.

4.1 South Africa

Hey (1952) in the Cape Province of South Africa recommends the use of 2 tons of horse or cattle manure per ha (1 ton per acre) or 500-1,000 kg per ha of poultry manure. Compost if used should have a carbon to nitrogen ratio of 10:1 and the addition of 68 kg of sodium nitrate per ha of compost is recommended. This and other organic manures should be dug into the soil before filling, having been spread evenly on the pond bottom, or if applied while the pond is full, should be placed in heaps around the perimeter to avoid excessive de-oxygenation. Van Schoor also mentions the use of fowl manure (1959 and *in litt.*).

Lombard (1959) recommends 4 to 14 tons of manure or compost per acre in addition to inorganic phosphate fertilizer, but cautions that this should be spread over the whole season and not applied in bulk to avoid oxygen deficiency.

In Natal Crass (*in litt.*) states that ducks at a rate of 1,200 per ha were the most effective means of fertilizing ponds and that fowl manure was twice as expensive as phosphate in order to achieve a comparable result.

4.2 Central Africa

Belgian workers achieved high production using waste grain, cereals and other industrial by-products; de Bont (1950) used as much as 10 tons/ha of mill sweepings. In a subsequent paper he mentions (1952) that 5,000-9,000 kg/ha of fish were obtained with the use of mill sweepings which would serve partly as food and partly as fertilizer. With manures alone he had productions from 1,000-2,000 kg/ha. This author suggests digging cotton seed, ground nut seed and sunflower seed cake into the pond bottom after an application of 1.5 tons/ha. Farmyard manure at 3 tons/ha may be necessary only every two years. The use of composted water weeds, particularly Characeae which may be dug in when the pond is dry or scattered on the water, is also stated to be efficacious. As a precaution, when organic manure is applied in quantity a good inflow of well oxygenated water is necessary. Gruber (1960) recommends animal manures and composts at 3,000 kg/ha before filling and subsequent applications which should not exceed 10,000 kg/ha/annum. Recommendations at a meeting on fish culture in the previous Belgian Congo were 3,000 kg/ha of compost and farmyard manure after each draining.

Charpy (1956) mentions that little benefit seems to be had from the use of industrial by-products as organic manures rather than as food, but in the same paper quotes production of 9,000 kg/ha in tilapia ponds at an agricultural station in the previous French Congo resulting from the combined rearing of pigs and fish.

4.3 Cameroon

In Cameroon the use of the Coypu (*Myocastor coypus*) for weed control is reported to have also the effect of providing useful food and manure for the fish as has been found elsewhere (Bard, 1965).

4.4 Madagascar

In Madagascar Kiener (1957) recommends addition of nitrogen, potash and bonemeal to a compost of grass which is applied when mature at 3,000 kg/ha.

4.5 Nigeria

In Nigeria grass from the banks and pond walls is composted and applied in ponds. To what extent these heaps serve as nurseries for fish food are eaten, or are acting as fertilizers, is not clear. However, in most cases the combination of grass compost and phosphate provides excellent results and increases the volume of plankton.

4.6 Rhodesia

In Rhodesia (van der Lingen, 1960) the use of pig manure gave net productions of up to 2,000 kg/ha, while ducks when kept on or near ponds at rates of 1,000 ducks per ha were able to ensure up to 4,000 kg/ha. In Northern Rhodesia (1958) also ducks have been used with good results.

5 GREEN MANURES

Lombard (1959) in the Transvaal advocates green manure in tilapia nursery ponds which are sown sparsely with an appropriate crop and filled a week before stocking without ploughing in the plants. If beans or other vegetables are grown the crop is harvested and the stalks left as a fertilizer. Gruber (1960) suggests that *Lagarosiphon* may be used in flooded ponds or rice grown and inundated at a height of 20-30 cm, this crop being especially valuable for *Tilapia melanopleura*. In these cases the effect is mainly a direct one as the green crop is eaten by the fish. This author also suggests the use of the dry pond bottom for a crop which is alternated with fish, but states that in the Central African territories this is not common. In Cameroon (Anon, 1957) maize is used as an alternating crop in a rotational system, but it is felt that the practice of green manuring and cropping does not give as high a yield as intensive feeding.

6 DRYING OF PONDS

The drying of ponds is implied or specifically recommended in many areas in Africa. This is usually associated with the amelioration of the bottom by liming, organic or other fertilizing and the removal of excess silt. Recommendations in the previous Belgian Congo were that a pond should be dried for 18 days and during this period compost applied to the bottom. Huet (1957) points out that the advantages are well-known and suggests either simply drying out to allow mineralization or a combination with a cropping practice. He recommends that the optimum period be determined. There is apparently no need to keep ponds dry for as long as in European practice but the weight of opinion seems to suggest that some benefit at least is obtainable. It is noticeable that production may drop in ponds under continual culture (Depasse, 1956), and there may well be much in favour of a closer study of drying and cropping particularly in areas of poor soil and water fertility. This author attributes the drop in yield to the absence of a long dry period.

7 CONCLUSIONS

While there is already a large body of work on fertilizers it is clear that more detailed information is required. The fertilization practices are likely to require modifications in tropical and sub-tropical waters but much use can be, and has been, made of experiences elsewhere in the world. There are many different approaches and different economical and social environments in which fish culture is pursued. In many parts of Africa fish culture is being successfully carried out in water bodies not designed primarily for fish production, and these pose special problems of their own vis-a-vis fertilization. The effects of fertilizers on all biological phases culminating in fish production need further investigation and it is hoped that in the next few years more critical studies will be made in this field.

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9 REFERENCES

Bard, J., 1962 Ou en est actuellement la pisciculture africaine? Bois For.Trop., (83):31-47

__________, 1965 Végétaux aquatiques tropicaux. Bois For.Trop., (99):3-11

C.C.T.A./C.S.S., 1954 Record of Symposium on African hydrobiology and inland fisheries, October, 1952 at Entebbe, Uganda. Publ.Cons.sci.Afr.S.Sahara, (6):153 p

__________, 1956 Record of Symposium on African hydrobiology and inland fisheries, Brazzaville 1956. Publ.Cons.sci.Afr.S.Sahara, (25)

__________, 1960 Third Symposium on hydrobiology and inland fisheries, Lusaka, 1960. Publ.Cons.sci.Afr.S.Sahara, (63):244 p.

Capart, A., and J. Kufferath, 1957 Considérations biologiques sur la pisciculture au Congo Belge. Bull.agric.Congo belge, 48(5):1245-61

Charpy, B., 1955 La pisciculture du Tilapia. Bull.franç.Piscic., (178):5-20

__________, 1956 Rôle de la nourriture dans la production des étangs à tilapia. Publ. Cons.sci.Afr.S.Sahara, (25):191-2

Conférence piscicole anglo-belge, Elisabethville (Congo Belge), 13-18 juin 1949.
1950 Comptes rendus. Bruxelles, Ministère des Colonies, 350 p.

de Bont, A.F., La culture des tilapia. In Comptes rendus de la conférence piscicole
1950 anglo-belge, Elisabethville (Congo Belge), 13-18 juin 1949. Bruxelles, Ministère des colonies, pp.321-36

___________, La production de poisson au Congo Belge (Méthode préconisée). Bull.
1952 agric.Congo belge, 43(4):1053-68

___________, Station de recherches piscicoles à Kipopo. Rapports Annuels No. 6 and
1956 No. 7, 1954-1955. Bull.agric.Congo belge, 47(4):1089-165

Depasse, P., Monographie piscicole de la Province Orientale. Bull.agric.Cong belge,
1956 47(4):959-1088

FAO/UN, Experimental fish culture project in Uganda; based on the work of A.G. Wurtz,
1961 FAO/TA inland fisheries biologist. Rep.FAO/E.T.A.P. (1387):32 p.

Fogg, G.E., Studies in nitrogen fixation by blue-green algae I. Brit.J.exp.Biol.,
1949 19:78-87

Gruber, R., Considérations sur l'amélioration des rendements en pisciculture congolais.
1960 Bull.agric.Congo belge, 51(1):139-57

Hey, D., Culture of fresh-water fish in S.Africa. 3rd ed. Cape of Good Hope, S.
1952 Africa, Inland Fisheries Dept., 126 p.

Huet, M., Dix années de pisciculture au Congo Belge et au Ruanda - Urundi Compte
1957 rendu de mission piscicole. Trav.Sta.Rech.Groenendaal, D(22):109 p.

Kiener, A., Elevage du tilapia à Madagascar. Bulletin de Madagascar, 124:762-784
1956

___________, Recherces piscicoles et development de la pisciculture dans la Grand
1957 Ile au cours de 1956. Bull.Madagascar, (136):739-66

Le Roux, P.J., Physical and biological changes following fertilization of water.
1955 Proc. of 3rd Interprov. Inland Fisheries Conference, Lydenburg 41-43. Transvaal Provincial Administration, South Africa

Lombard, G.L., A preliminary guide to fish-farming in the Transvaal. Fauna and Flora,
1959 (10):17-60

___________, Four years of experimental culture of Tilapia mossambica in the Trans-
1960 vaal. Publ.Cons.sci.Afr.S.Sahara, (63):225-8

Maar, A., Tilapia culture in farm dams in S. Rhodesia. Rhod.agric.J., 53(5)667-87
1956

Mortimer, M A.E., A handbook of practical fish culture for Northern Rhodesia.Dept. of
1961 Game and Fisheries, Lusaka, 150 p. (mimeo)

___________, Annual report on fish culture in N. Rhodesia Dept. of Game and Fisheries,
1962 Lusaka, 20 p. (mimeo)

Northern Rhodesia. Dept. of Game and Fisheries. Annual Report, 1957, Lusaka, Govt.
1958 Printer

___________, Annual Report, 1962, Lusaka, Govt. Printer
1963

Simpson, C.J.H., Fish farming practice. Rep.Dep.Game Fish.Uganda, Appendix 3
1955

___________, Notes on the Kajansi fish farm Uganda. Publ.Cons.sci.Afr.S.Sahara, (25)
1956

Sklower, A., Fishfarming and fresh-water biology in Northern Rhodesia. Arch.Hydrobiol.,
1951 55:284-303

van der Lingen, M.I., The use of animal manures and the integration of animal keeping
1960 and fish culture in tilapia culture. Publ.Cons.sci.Afr.S.Sahara (63):212-6

van Schoor, D.J., Fertilization of fish ponds. Rep.Dep.Nat.Conserv.Cape Prov., (16):
1959 65-8

van Someren, V.D., and P.J. Whitehead, The culture of *Tilapia nigra* (Günther) in ponds
1959 on Papaers in E.Afr.agric.J., 25 et seq.

Anon., Rapport d'activité de la section de peche et pisciculture pour l'année 1957.
1957 Cameroun, Eaux et Forets. 59 p. (mimeo)

___________, Comptes rendus d'une réunion relative à la pisciculture au Congo Belge
1958 et au Ruanda Urundi. Bull.Inf.I.N.E.A.C., 7(2):128-32

___________, Carp farming on the Jos Plateau. Bull.Inst.franc.Afr.Noire, 25(1):285-98
1963

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II/R-6

THE ROLE OF SOIL IN FISH POND PRODUCTIVITY IN ASIA AND THE FAR EAST

by

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Abstract

The paper reviews briefly some roles of soil in the mechanism of fish production in various kinds of fish culture in Asia and the Far East. Supply of nutrients from environs and bottom soil, relationship between mineralization of precipitated organic matter and properties of soil, and transformation of nutrient compounds with the change in physico-chemical conditions in soil and with various practices such as drying, furrowing and liming are discussed. Attention is drawn to problems which need to be studied further.

LE ROLE DES SOLS DANS LA PRODUCTIVITE DES ETANGS DE PISCICULTURE EN ASIE ET EN EXTREME-ORIENT

Résumé

Cette communication passe succinctement en revue certains aspects du rôle des sols dans le mécanisme de la production de poisson dans divers types d'élevage en Asie et en Extrême-Orient. Diverses questions sont examinées : l'apport d'éléments nutritifs en provenance du sol des environs et du fond de l'étang, les rapports entre la minéralisation de la matière organique précipitée et les caractéristiques du sol et enfin la transformation des composés nutritifs en fonction de la modification des conditions physico-chimiques du sol et de diverses pratiques telles que l'assec, le labourage et le chaulage. L'attention est attirée sur certains problèmes qui demandent à être étudiés plus à fond.

LA FUNCION DEL SUELO EN LA PRODUCTIVIDAD DE LOS ESTANQUES PISCICOLAS EN ASIA Y EL LEJANO ORIENTE

Extracto

En este documento se examinan sumariamente algunas de las funciones de los suelos en el mecanismo de la producción piscícola en varias clases de piscicultura de Asia y el Lejano Oriente. Se estudia el suministro de elementos nutrientes de los alrededores y del suelo del fondo, la relación entre la mineralización de la materia orgánica precipitada y las propiedades del suelo, y la transformación de los compuestos nutrientes con el cambio de las condiciones físico-químicas del mismo, así como de varias prácticas tales como el desecado, trazado de zanjas y adición de cal. Se señalan, para su atención, los problemas que necesitan ser estudiados más a fondo.

1 INTRODUCTION

Soils have several roles in the production of fish from ponds; in supplying nutrients to the inflowing water, in the mineralization of organic bottom deposits, and in the storage and release of nutrients to the water. They also provide shelter and food for bottom-dwelling organisms (an aspect not included in this review).

2 SUPPLY OF NUTRIENTS FROM ENVIRONMENT

The natural waters supplying fish ponds contain various dissolved substances which are essential for fish production. According to Schuster (1949), substances carried into the pond with the water are the main source of nutrients in Java, where ponds are not manured and the river water contains extraordinarily large quantities of nutrients as it is mostly drawn from volcanic mountains. Eruptions of the big volcanoes in East Java help to maintain the productivity of "tambaks" in Surabaya and Sidoardjo. Kobayashi (1958; 1960) analysed thousands of water samples of natural surface waters in Japan and South-East Asia and emphasized the close relationship between the mineral composition of the water and the geological properties of the basin.

Correlations have been found between concentration of minerals in river water and fish production (Moritsugu and Kobayashi, 1960), which is to be expected as the production of fish food depends on the minerals. Hickling (1962) noticed that the greater the supply of natural food in a pond, the greater the amount of supplementary food that can be given. It may mean that the greater the production of natural food, the greater would be the effect of supplementary food on the fish crop. So the use of water flowing over a fertile soil may also be beneficial in running-water fish ponds where intensive feeding is usually carried out. The value of such rich waters is generally recognized by running-water carp culturists in Japan.

3 SIGNIFICANCE OF DECOMPOSITION AND STORAGE

The nutrients brought in with the inflowing water are usually insignificant compared with those supplied from the pond bottom in stagnant fish ponds (Hickling, 1962). However, intensive fish culture is most widely conducted in stagnant ponds in Asia and the Far East by heavy fertilization with organic manures and/or intensive feeding with artificial or supplementary foods. In Chinese fish culture, the techniques of which are summarized by Chou et al. (1961), almost no attention is paid to the supply of nutrients from the bottom soil.

Fertile soil is the best for pond construction, because of its capacity to supply nutrients to the water, but in practice land unsuitable for agriculture is generally used, since such land can give a better income as fish ponds than in any other way (as advocated by Schäperclaus, 1933; Schuster, 1949; Chou et al., 1961; Hickling, 1962). The Tropical Fish Culture Research Institute at Malacca is carrying out pioneer experiments in the use of "gelam" soil, which is sterile and even toxic for agriculture because of the high sulphate content (Malacca, 1960; 1961; 1962; 1963). At Malacca the pond water remained neutral in the acid soil ponds because of the strongly absorptive ferric hydroxide on the surface of the pond bottom (Hickling, 1962). The liming of these ponds had no significant effect on the fish crop, but the application of about 2.2 kg P_2O_5/ha, without any limestone, had a remarkably significant effect (increasing the crop from 104 kg/ha to 232 kg/ha per six months), and harvests of about 900 kg/ha in six months were obtained with 90 kg P_2O_5 when proper combinations of species were stocked.

The retention of phosphorus in the pond soil and a residual effect on fish production were recognized at Malacca (Hickling, 1962; Malacca, 1963). The residual effect of phosphate fertilizer has been proved in Europe (Mortimer and Hickling, 1954; Hickling, 1962). The conversion of phosphate fertilizer into fish at Malacca was surprisingly more efficient (30 kg P_2O_5 with 10 kg fish) compared with conversion in European carp ponds and American bass ponds , which was probably because the fishes at Malacca feed directly on the plant growth stimulated by the fertilizer (Prowse, 1962; 1963; 1964).

Preliminary experiments have shown that precipitated phytoplankton was not well-decomposed in a pond with a concrete bottom, remaining as a green gelatinous layer several centimeters thick, whereas no such layer remained on sand- or paddy-soil bottoms (Matida, unpublished report). These trials have indicated how pond soil effectively decomposes precipitated organic matter, accelerating the turnover of nutrients, and retaining some nutrients in it. Even in running-water fish culture the benefits of using mud ponds or natural streams are commonly recognized by trout and sweetfish (Plecoglossus altivelis) culturists because they have a remarkable capacity for self purification, making frequent cleaning unnecessary. In addition, sweetfish utilize algae attached to the gravels and never suffer from malnutrition (Hidaka, pers. comm.).

Although there has been no thorough experimental work on the relation between the size of particles and decomposing activity in fish ponds, Chou et al. (1961) recognize that extremely fine particles such as clay are not suitable for Chinese fish ponds, where a great deal of organic manure and/or supplementary foods are used. Lin (1940) and Chou (1961) state that as the organic matter exceeds the decomposing capacity of the pond soil, ponds must be dried, and mud must be taken off once every one or two years. In the above-mentioned experiment there was no significant difference between paddy-soil and sand as far as decomposing activity is concerned.

The preference for different types of soil varies with the type of fish culture, as exemplified by the brackish-water fish ponds of the Philippines and Java. Frey (1947) found that the greatest production of algae, on which the milkfish (Chanos chanos) feed, occurred in ponds having bottoms of peaty clay, either compact or matter in structure, or slimy clay, slightly organic and gelatinous in consistency, while the least production was associated with sandy bottoms. According to Schuster (1949), ponds are flooded with fertile estuarine water during the incoming tide and neither artificial fertilizers nor supplementary foods are used. The main roles of pond soil in fish culture seem to be the accumulation of nutrients brought in by the tides and the provision of a living place for benthic algae. Colloidal matter on the surface of bottom soil may have a very important role in this respect. The retaining of nutrients by soil colloids is well appreciated in European fish ponds, where fishes are raised with inorganic fertilizers and artificial foods, and considerable literature on this role of soil has been cited by Mortimer and Hickling (1954) and Maciolek (1954).

The decomposition of organic matter withdraws large quantities of oxygen and may cause an oxygen deficiency. Deoxygenated or anaerobic conditions are avoided in all types of fish culture. Sano and Matsue (1957a, b) considered that dissolved oxygen was one of the most important factors controlling fish production in Japanese eel ponds. If deoxygenation becomes so intense that anaerobic or reducing conditions occur, various toxic substances are produced. Among them hydrogen sulphide has been studied extensively. In ponds where the water is rich in sulphate (for example in saline water) the reduction of sulphate ions to hydrogen sulphate easily occurs, and its presence in the bottom water or soil makes it impossible to raise fish in certain ponds.

Traditional measures to overcome deoxygenation include drying, liming and eliminating sludge. To improve the soil of prawn ponds in wet rice fields which cannot be drained, the bottom water is drained off through perforated pipes installed under the surface of the bottom sand (Yamamoto et al., 1960). In this case, the bottom water contaminated with excreta and food residue is merely discharged through the bottom sand, on which prawns creep and eat food, or in which they hide. But the water may be reused, since the decomposition or purification activity of sand can be utilized and the water can be mechanically oxygenated if necessary. In order to keep the bottom soil in oxidized condition, the drained water may have to contain more than 8 percent of oxygen. The observation of Pearsall and Mortimer (1939) is relevant in this respect. Such a technique is widely employed in aquaria. Saeki (1958) studied the relationship between the purification capacity of a sand filter, size of sand and amount of sand. Saeki and Aoe (1962) succeeded in raising 500 kg of carp by re-using 205 m^3 of water. Chiba (private communication) found that nitrogen introduced as food in an aquarium was retained as nitrate and fish flesh; a recognizable loss of nitrogen was not observed. In this experiment water was kept neutral by occasional addition of sodium bicarbonate.

4 MECHANISM OF TURNOVER

It is well known that bottom water contains many nutrients and vertical mixing by wind force or thermal convection is one of the most important mechanisms controlling the productivity of natural lakes and certain fish ponds. Maciolek (1954) has summarized the work on this subject with special reference to pond fertilization. The main reasons why fish ponds should not be too deep are related to this factor and the need for proper aeration.

Mortimer (1941; 1942; 1949; 1959), Inaba (1961) and Hickling (1962) have explained the reasons for diurnal or seasonal fluctations of dissolved oxygen of the bottom water and its role in production. Nutrient ions are produced by the decomposition of precipitated organic matter. Under oxidizing conditions the ions, except nitrite and nitrate ions, are adsorbed on soil colloids composed of clay minerals, ferric hydroxide, humus and so forth, and these ions are released into the water under reducing conditions. Stephenson (1951) also found that phosphate was given off rapidly from surface layers of estuarine mud when the supernatant water becomes de-oxygenated; he thought that the phenomenon might be partially due to catastrophic biological changes. If these released nutrients are then distributed in the pond water, they are taken up by plants, and thence by fish. Although ferrous ions may also be released and oxidized, the amount of ions adsorbed on colloidal ferric hydroxide will decrease when it is diluted in the upper layer, since Freundlich's adsorption isotherm suggests that the amount of ions adsorbed per unit weight of colloidal matter decreases in more dilute conditions. Furthermore, the nature of colloidal matter in supernatant water may be different from that on the pond bottom, though this problem has not been much studied. Freundlich's adsorption isotherm is recognized as the most widely applicable to adsorption in liquids, and the equation was also found to be applicable for pond water (Matida, 1956).

Ohle (1938) found that by raising pH, nutrients such as phosphate adsorbed on ferric hydroxide were easily washed out, and this may explain why nutrients are easily released in the more alkaline upper water. This amphoteric property of ferric hydroxide also explains how nutrients adsorbed by pond mud may be released even under oxidizing conditions if the ambient water is alkaline.

Nutrients are precipitated not only as dead organisms but also in other forms. Einsele (1938) considered that phosphate ions are precipitated as ferric phosphate, but Mortimer and Hickling (1954) prefer to regard the precipitation process as one of adsorption of phosphate ions on colloidal ferric hydroxide, because the concentration of phosphate decreases well below the concentration calculated from the solubility of ferric phosphate. Hepher (1958) indicated that in the very calcareous pond muds of Israel, most of the added phosphate is fixed in the pond mud as insoluble calcium phosphate. Suspended matter of 0.5 to 1.2 µ was analyzed from a fertilized pond, where the amount of phosphate applied was well below the solubility of calcium phosphate (Matida, 1956), and the content of inorganic phosphorus in the suspended matter was found to be higher in deeper layers than in the surface layer. Enough iron could not be detected in the particles to satisfy the stoichiometric relation of ferric phosphate. There may be other processes of precipitation by the adsorption of phosphate ions on detritus and silt.

5 TRANSFORMATION OF NUTRIENTS IN SOIL

The analogy between rice fields and fish ponds is not complete, as aquatic organisms depend mostly on the nutrients released into the water by the decomposition of precipitated matter, mainly organic matter as mentioned above, but rice plants depend on the nutrients in the mud itself. Knowledge of the chemistry of waterlogged soil, especially chemical processes in it, depends largely on the researches on rice field soil. Various aspects of these researches on rice field soil of significance in fish culture have been summarized by Hickling (1962).

As in certain fish ponds, the upper soil of rice fields is furrowed when it is dried. After flooding the furrow slice is in a reduced condition, except for the surface layer in contact with the supernatant water. According to Shiori and Aomine (1940) and Aoki (1941), mixing in organic manures, drying well before flooding, or making neutral or slightly alkaline by liming, decreases the redox potential of the subsurface soil, and the formation of ammonia, ferrous ions and sulphide ions after flooding are thereby accelerated, and the availability of phosphate is also increased. The effects of these practices are believed to make organic compounds more easily decomposable. In the three to ten mm thick top layer, nitrate, sulphate and ferric ions are stable, and the redox potential is always higher than 0.3 volts at pH 5. In the lower layer, ammonia, sulphide and ferrous ions are stable, according to Shioiri and Tanada (1954). These results agree with observations in lakes by Pearsall and Mortimer (1939) and Mortimer (1941; 1942).

The chemical changes mentioned above are accompanied by an increase in pH and the sorption capacity of soil to ammonia and phosphate (Kawaguchi, 1950). These physico-chemical properties of paddy soil after flooding not only minimize the losses of nutrients by seepage and water exchange, but also increase the availability of nutrients. They may explain the role of pond soil as a reservoir of phosphorus in fish ponds and the residual effect of phosphorus. Osugi et al. (1932 - cited in Kawaguchi, 1950) and Lu and Chung (1964) have studied the solubilities of various phosphate minerals under different pH values. Solubilities of most phosphates increase under alkaline conditions. These results also explain the mechanism of phosphorus cycle in fish ponds. According to Watts (1965a,b), most phosphates in the pond mud of Malacca are organic - and occluded - forms, and the remainder chiefly in association with iron, aluminium or calcium in the layer. He also found that the retention capacity of fresh mud was higher than that of air-dried mud, and the depth of penetration of phosphorus was about 2 cm.

It is generally recognized that nitrate is less effective than ammonia in rice fields. This is partly due to the escape of nitrate ions with water exchange because nitrate is not well adsorbed by soil compared with ammonia (Kawaguchi, 1950). In addition nitrate is reduced to nitrogen by chemical and biological processes at the boundary of reducing and oxidizing layers. Shioiri and Tanada (1954) confirmed the occurrence of nitrogen loss by this process by determining the increase in nitrogen gas and the decrease in nitrate. Furthermore, it is well known that some blue-green algae can fix very considerable quantities of atmospheric nitrogen. Although the exact form in which it is fixed is not known, an excess is excreted into the water, and the present author (Matida, 1956) confirmed that the amount was enough to make the application of nitrogen fertilizers unnecessary. It is well known that some soil bacteria also fix atmospheric nitrogen (Kawaguchi, 1950) but its practical significance is unknown. This may explain why the effect of nitrogen fertilizers is not well evaluated in fish ponds.

The behaviour of phosphates and nitrates in shallow sea soil is similar to that in rice field soil, and has been studied by Okuda (1953a,b; 1955a,b; 1957a,b).

6 DEGRADATION OF SOIL

The existence of areas of podzolic or degraded rice field soil is well recognized by soil scientists. In such soils the content of free iron, active manganese and phosphorus in the furrow slice is far less than in normal rice field soil, and sulphuretted hydrogen is easily liberated under the reduced conditions. This condition is remedied by mixing surface and deep soil, or by enriching iron and manganese. The electrokinetic potential difference (zeta potential) of negatively charged soil colloids is decreased by ferrous ions under neutral or slightly acid conditions. Shioiri and Nishigaki (1938) observed that the zeta potential of soil colloids is decreased under reducing conditions by the ferrous ions liberated, and they concluded that the elluviations of iron, manganese, phosphorus and organic matter in rice field soil are ascribable to the decrease in zeta potential. Shioiri and Yokoi (1950) also found that the leaching was accelerated by peptization of ferrous sulphide with excessive sulphuretted hydrogen.

It may not be unreasonable to expect that similar degradation of pond soils occur. In addition, precipitated organic matter and sulphate ions in saline water supply much sulphur in excess of the active iron in pond soil. Koyama and Sugawara (1951) found that sulphate ions in water were taken into soil by co-precipitation. The degradation of fish pond soil by the processes mentioned above is thought to have made Japanese eel culturists employ the technique of rice farmers; namely, the application of low-grade iron ore (Satomi, private communication).

7 FUTURE STUDIES

Nitrogen and phosphorus in pond soils have been studied by many workers but enough attention has not been paid to trace elements. Henderson (1949) found that the application of manganese promoted the growth of phytoplankton in a pond. Mortimer (1939) also found that the lack of some unknown nutrients, which were normally brought in from the surrounding land, limited the production of algae in a lake. These examples, the general productiveness of soil drainage and the successful use of soil extracts in algal cultures, all seem to suggest that studies on the cycles of trace minerals and other unknown growth-promoting substances will become important. Such a study has already been initiated by Donaldson, Olson and Donaldson (1959) in a cold-water lake.

In addition, most chemical studies of bottom soil have been mainly focused on the tracing of chemical transformations which connect both processes of supply and consumption in the cycle of nutrient elements. More studies on the nature of soil colloids seem to be necessary in order to fully understand the mechanisms of various chemical changes in pond soil.

8 REFERENCES

Aoki, M., 1941 Studies on the behavior of soil phosphoric acid under paddy field condition (1). *J.Sci.Soil, Tokyo*, (15):182-202

Chou, U. *et al.*, 1961 Fresh-water fish culture in China. Peking, Science Publishing House. 612 p.

Donaldson, L.R., P.R. Olson and J.R. Donaldson, 1959 The Fern Lake trace mineral metabolism program. *Trans.Amer.Fish.Soc.*, 88:1-6

Einsele, W., 1938 Über chemische und kolloidchemische Vorgänge in Eisen-Phosphat-Systemen unter limmochemischen und Limnogeologischen Gesichtspunkten. *Arch.Hydrobiol.(Plankt.)*, 33:361-87

Frey, D.G., The pond fisheries of the Philippines. J.Mar.Res., 6:247-58
1947

Henderson, C., Manganese for increased production of water-bloom algae in ponds. Progr.
1949 Fish.Cult., 11(3):157-9

Hepher, B., On the dynamics of phosphorus added to fish ponds in Israel. Bamidgeh, 10(1):
1958 3-18

Hickling, C.F., Fish culture. London, Faber and Faber, 295 p.
1962

Inaba, D., Fresh-water fish culture. Tokyo, Koseisha Koseikaku. 318 p.
1961

Kawaguchi, K., Chemistry of the soil, No.6. Chemistry of paddy soil. Tokyo, Yokendo.
1950 89 p.

Kobayashi, J., Chemical studies of the rivers in South East Asia. Nogaku Kenkyu, 46(2):
1958 63-112

__________, Studies on the average water quality and characteristics of Japanese rivers.
1960 Nogaku Kenkyu, 48(2):63-106

Koyama, T. and K. Sugawara, Sulphate co-precipitation in lake and sea and its concentration in the bottom deposits. J.oceanogr.Soc.Japan, 6(4):190-1
1951

Leitritz, E., Trout and salmon culture. Fish.Bull., Sacramento, (107):169 p.
1959

Lin, S.Y., Fish culture in ponds in the new territories of Hong Kong. J.Hongkong Fish.
1940 Res.Sta., 1(2):161-93

Lu, R.K. and P.F. Chung, On the availability and transformation of crystalline iron phosphate (strengite) in acidic paddy soils. Sci.sin., 13(1):93-6
1964

Maciolek, J.A., Artificial fertilization of lakes and ponds. A review of literature.
1954 Spec.sci.Rep.U.S.Fish Wildl.Serv.-Fish., (113):49 p.

Malacca, Tropical Fish Culture Research Institute, Rep.trop.Fish.Cult.Res.Inst., 1957-9
1960

__________, Rep.trop.Fish.Cult.Res.Inst., 1959-60
1961

__________, Rep.trop.Fish.Cult.Res.Inst., 1960-61
1962

__________, Rep.trop.Fish.Cult.Res.Inst., 1961-62
1963

__________, Rep.trop.Fish.Cult.Res.Inst., 1963
1964

Matida, Y., Study of farm pond fish culture. No.3. Fates of fertilized elements and the relationship between the efficiency of fertilizer and bio-chemical environment in the pond. Bull.Freshw.Fish.Res.Lab., Tokyo, 6(1):27-39
1956

Moritsugu, M. and T. Kobayashi, Study of trace metals in bio-materials (1). Geographical
1960 difference of metals contained. *Nogaku Kenkyu*, 47(3):149-88

Mortimer, C.H., Physical and chemical aspects of organic production in lakes. *Ann.appl.*
1939 *Biol.*, 26:167-72

__________, The exchange of dissolved substances between mud and water in lakes.
1941 *J.Ecol.*, 29:280-329

__________, The exchange of dissolved substances between mud and water in lakes.
1942 *J.Ecol.*, 30:147-201

__________, Seasonal changes in chemical conditions near the mud surface in two lakes
1949 of English Lake District. *Verh.int.Ver.Limnol.*, 10:353-6

__________, The physical and chemical work of the Freshwater Biological Association,
1959 1935-57. *Advanc.Sci.*, 61:524-30

Mortimer, C.H. and C.H. Hickling, Fertilizers in fish ponds. *Fish.Publ.Lond.*, (5):155 p.
1954

Ohle, W., Die Bedeutung der Austauschvorgänge Schlamm und Wasser für den Stoffkreislauf
1938 der Gewässer. *Vom Wasser*, 13:87-97

Okuda, T., On the soluble nutrients in bay deposits. 1. An examination on the soluble
1953a nutrients in bay deposits. *Bull.Tohoku Fish.Res.Lab.*, 2:109-17

__________, On the soluble nutrients in bay deposits. 2. On the possibility of supply
1953b of the nutrients of muddy deposits into the sea water by bottom harrowing.
Bull.Tohoku Fish.Res.Lab., 2:118-25

__________, On the soluble nutrients in bay deposits. 3. Examinations on the diffusion
1955a of soluble nutrients to sea water from mud. *Bull.Tohoku Fish.Res.Lab.*, 4:215-42

__________, On the soluble nutrients in bay deposits. 4. An experiment on the behaviour
1955b of phosphate-phosphorus between mud and sea water. *Bull.Tohoku Fish.Res.Lab.*,
5:79-91

__________, On the soluble nutrients in bay deposits. 5. Influence of the temperature
1957a on the formation of ammonia-N and phosphate-P during the storage of bottom
muds. *Bull.Tohoku Fish.Res.Lab.*, 9:143-50

__________, On the soluble nutrients in bay deposits. 6. Seasonal changes of the in-
1957 organic nitrogen and phosphorus in the pore water of bottom muds. *Bull.Tohoku
Fish.Res.Lab.*, 9:151-64

Pearsall, W.H. and C.H. Mortimer, Oxidation-reduction potentials in waterlogged soils,
1939 natural waters and muds. *J.Ecol.*, 22:483-501

Prowse, G.A., The use of fertilizers in fish culture. *Proc.Indo-Pacif.Fish.Coun.*,
1962 9(2):73-5

__________, Neglected aspects of fish culture. *Curr.Aff.Bull.Indo-Pacif.Fish.Coun.*,
1963 (36):10 p.

__________, Some limnological problems in tropical fish ponds. *Verh.int.Ver.Limnol.*,
1964 15:480-4

Saeki, A., Studies on fish culture in the aquarium of closed-circulating system. Its
1958 fundamental theory and standard plan. *Bull.Jap.Soc.sci.Fish.*, 23(11):684-95

Saeki, A. and M. Aoe, An example of raising one ton of carp in a closed-circulating pond.
1962 *Aquiculture, Tokyo*, Extra Ed. (1):13-27

Sano, K. and Y. Matsue, Oxygen metabolism in eel culture ponds. 1. Theoretical fish
1958a culture methods based on oxygen metabolism. *Aquiculture, Tokyo*, 6(1):43-9

__________, Oxygen metabolism in eel culture ponds. 2. The application of theoretical
1958b fish culture method for eel cultures. *Aquiculture, Tokyo*, 6(1):50-5

Schäperclaus, W. and F. Hund, Textbook of pond culture. Rearing and keeping of carp, trout
1933 and allied fishes. *Fish.Leafl.Wash.*, (311):260 p.

Schuster, W.H., Fish culture in brackish-water ponds of Java. *Spec.Publ.Indo-Pacif.Fish.*
1949 *Coun.*, (1):143 p.

Schuster, W.H., G.L. Kesteven and G.E.P. Collins, Fish farming and inland fishery management
1954 in rural economy. *FAO Fish.Stud.*, (3):64 p.

Shiori, M. and S. Aomine, The effect of drying the paddy soil before flooding. *Spec.Rep.*
1940 *agric.Exp.Sta.*, 30 p.

Shiori, M. and S. Nishigaki, Colloidal behaviour of waterlogged paddy soil. *J.Sci.Soil,*
1938 *Tokyo*, (17):287

Shiori, M. and T. Tanada, The chemistry of paddy soil in Japan. Tokyo, Ministry of Agriculture
1954 and Forestry, 46 p.

Shiori, M. and H. Yokoi, The leaching mechanism of iron sulphides in degraded rice soils.
1950 *J.Sci.Soil, Tokyo*, 20:157-61

Stephenson, W., Preliminary observations upon the release of phosphate from estuarine mud.
1951 *Proc.Indo-Pacif.Fish.Coun.*, Sect. 3:184-9

Watts, J.C.D., Liming of the local acid sulphate soils. *Invest.Rep.trop.Fish.Cult.Res.*
1965a *Inst.*, (1):4 p.

__________, The chemical analysis of muds from the pond system of the Tropical Fish
1965b Culture Research Institute. *Invest.Rep.trop.Fish.Cult.Res.Inst.*, (3):9 p.

Yamamoto, T. *et al.*, The under-drain for the shrimp culture pond. Its purpose, method of
1960 construction, and effect. *Aquiculture, Tokyo*, 8(2):133-7

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FERTILIZATION OF WARM-WATER FISH PONDS IN EUROPE

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FERTILIZATION OF WARM-WATER FISH PONDS IN EUROPE

Abstract

The first part of the paper outlines the main problems of fertilization of fish ponds under European climatic and economic conditions. The change in opinions, from the theory of nitrogenless fertilization which was believed in during the period between world wars, to the modern approach that recommends *inter alia* nitrogenous fertilizers, is reviewed. The characteristics of Norway saltpetre, ammonium sulphate and liquid ammonia, which are the three commonly used fertilizers in pond culture, are given. Information concerning experiments conducted with urea and acidic ammonium carbonate is also presented. The second part of the paper reviews the use of the more important organic fertilizers.

LA FERTILISATION DES ETANGS DE PISCICULTURE A TEMPERATURE ELEVEE EN EUROPE

Résumé

Dans une première partie, la communication décrit les principaux problèmes que pose la fertilisation des étangs de pisciculture dans les conditions climatiques et économiques régnant en Europe. L'auteur examine les raisons pour lesquelles la théorie de la fumure sans azote, qui avait cours entre les deux guerres mondiales, a fait place à la théorie moderne qui recommande d'utiliser, entre autres, des engrais d'azotés. Il indique les caractéristiques du salpêtre de Norvège, du sulfate d'ammonium et de l'ammoniac liquide qui sont les trois engrais communément employés en pisciculture. Il présente également des renseignements concernant les expériences menées avec de l'urée et du carbonate acide d'ammonium. Dans une deuxième partie, la communication passe en revue l'utilisation des principaux types d'engrais organiques.

FERTILIZACION DE LOS ESTANQUES PISCICOLAS DE AGUAS TEMPLADAS EN EUROPA

Extracto

La primera parte del estudio expone los principales problemas de la fertilización de estanques piscícolas en las condiciones climáticas y económicas europeas. Se examina el cambio observado de opiniones que van desde la teoría de la fertilización sin nitrógeno, en la que se creyó durante el período comprendido de las dos guerras mundiales, al moderno método que recomienda *inter alia* fertilizantes nitrogenados. Se indican las características del nitrato potásico noruego, el sulfato amónico y el amoníaco líquido, que son los tres fertilizantes empleados generalmente en el cultivo en los estanques. Se ofrece también información sobre los experimentos realizados con urea y carbonato amónico ácido. En la segunda parte del estudio se examina el empleo de los fertilizantes orgánicos más importantes.

1 SOME PROBLEMS IN FERTILIZING FISH PONDS

1.1 Main aims

What fertilizers should be used to raise the fertility of ponds by creating better conditions for the development of natural fish food, thus reducing the volume of fodder consumed by carp (Cyprinus carpio L.)? Further, how can the oxygen conditions be improved in waters which are prone to violent deterioration when the fish are fed intensively (Szpet and Feldman 1959)? These basic questions, if answered, would open further prospects for a marked increase of fish production in warm-water ponds in Europe.

An additional problem concerns the quantitative and qualitative variation in the invertebrate fauna in ponds, as this falls to the minimum in August, just the month with the best thermal conditions for carp growth, for the carp is a warmth loving species. This bears on the deterioration of the optimum ratio of natural to artificial food (Gurzęda,1965).

Furthermore, the aims and practical aspects of pond fertilization in Europe must reckon with both the climatic conditions and the economic conditions in individual countries.

1.2 Climatic factors

The extent to which the European climate limits primary production is exemplified by two figures. The first is the average daily insolation, expressed in percent of the maximum possible insolation; according to Liebmann and Keitz (1965)this is 39 percent for the Experimental Pond Station at Wielenbach (Germany, Federal Republic). The second applies to the number of days during the year, with mean water temperature above 20°C; according to Stegman (1960) and Backiel (1964) this determines the level of fish productivity in ponds. At the Experimental Pond Station at Zabieniec near Warsaw, in the centre of the physical map of Europe, the period of time with water temperature above 20°C, averages no more than sixty days in the year.

1.3 Economic factors

The production of carp for the table in Europe is governed on the one hand by the climatic factor, and on the other by the generally higher quality standards set for the market compared with other countries outside Europe. The rearing of carp weighing between 0.5 and 2 kg requires at least two years under European climatic conditions. This involves splitting the carp production cycle into two years, setting out from fingerlings weighing between 25 and 100 g the first season, followed by about a six-month growthless winter period, then the required individual weight is attained by fish during the following season.

The oxygen demand of fry, nearly double that of two-year old carp (Priwolnjew, 1957; 1958) restricts the use of organic manures in fry ponds.

1.4 Chemical composition of fresh waters

We come now to the question of whether the chemical composition of European inland waters includes the biogenic constituents essential for photosynthesis in sufficient amounts to ensure full utilization of the solar energy.

The relatively scarce, rather superficial studies on the chemical composition of inland waters give only a general idea as to which biogenic constituents seem to limit photosynthesis in aquatic plants.

Mackareth ((1956), relying upon fairly ample analytical material, came to the conclusion that calcium, sodium and manganese do not restrict phytoplankton production. Rodhe (1948), reported that the optimal concentration of potassium in the case of Scenedesmus quadricauda is 1 mg per litre.

According to Lund (1956), mass-scale phytoplankton development is quite often encountered in lakes even at a potassium level within the limits of 0.04 to 0.4 mg K, but not as often as when it is within the limits of 0.4 to 2 mg/l.

Winberg (1953) and Braginski (1955; 1958; 1961) established that in many ponds on Byelorussian fish farms, in which the waters contained up to 4 mg/l/K, potassium was not a factor limiting the fish crop, and furthermore, the fishing effects remained unchanged whether potassium was administered by itself or together with phosphorus and nitrogen.

Stangenberg - Oporowska (1961) ascertained on the basis of ample material that the potassium level in Polish ponds keeps within 2 to 6 mg/l in most cases, and shows an upward trend from spring to autumn. As not much potassium is contained in phytoplankton (0.5 to 1 percent of the dry weight), there is very little likelihood of this constituent being in short supply.

In Germany and a number of neighbouring countries, phosphorus-potassium fertilization of ponds used to be employed in the inter-war period (Mortimer, 1954). In post-war times pond fertilization with potassium was generally abandoned except for peat ponds, which are as a rule scantily provided with this constituent. The level of phosphorus and nitrogen in European inland waters is however, unlike potassium, in short supply to a greater or lesser degree, and limits phytoplankton development.

The results of the present research on the influence of nitrogen on fish crops in ponds contradict those obtained by a number of German investigators after the first world war (Demoll, 1925; Wunder, 1949).

1.5 The phosphorus:nitrogen ratio

The ratio P:N seems to be an agent limiting the efficacy of nitrogenous fertilization of ponds. From among the few investigations on the subject in Europe mention should be made of the results obtained by Kuzmiczewa (1965).

Using Norway saltpetre at the rate of 1 mg/l/N in one group of ponds, 5 mg/l in another and 0.1 mg/l P in both cases, she obtained P:N ratios of 1 : 4 and 1 : 44 respectively. The extent to which the ratio of phosphorus to nitrogen can affect primary, secondary and final production is illustrated by the results given below.

Primary production in the two groups of ponds was 1.47 mg/l O_2 and 3.3 mg/l O_2 respectively. Not withstanding the differences in phytoplankton biomass, she obtained the same quantity of zooplankton in both groups, 4.4 mg/l in each case. She established no correlation between nitrogen concentration in the water and fish production (10.1 kg fish per pond and 13.8 kg/pond). Thus the phosphorus deficit clearly had an adverse effect on the full utilization of five times as great nitrogen concentration. The results obtained by Kuzmiczewa favour, therefore, the acceptance of P : N = 1 : 4, as determined by Swingle and Smith (1938), to be the optimum ratio.

The determination of the optimum P : N ratio is, however, a most difficult proposition in pond practice since both the bicarbonate level in the water and the acidity level in the bottom sediments are subject to constant variation during the vegetative season, which may affect the variation in P : N ratio. It would be reasonable to suppose that the ratio of phosphorus to nitrogen could be kept wider apart in well mineralized waters, and even more so in cases where the pond bottom is alkaline.

An inverse physico-chemical situation should be expected in ponds having soft water and in the presence of acidified bottom sediments. In such cases, the P : N ratio should be rather narrowed. Possibly that is the reason why Winberg and Ljachnowicz (1965) suggest the possibility of variation of the optimum P : N ratio within fairly broad limits, from 1 : 4 to 1 : 8.

The results of investigations conducted in the "Nivka" experimental ponds near Kiev (Feldman and Suchowij, 1961) also suggest that 1 : 4 P : N ratio is most favourable.

Lack of appreciation of the significant rôle played by the phosphorus-nitrogen ratio in pond fertilization was probably among the reasons underlying the promotion of the theory of nitrogenless fertilization of ponds (Demoll, 1925), based mainly on the research at Wielenbach where the waters are exceptionally rich in mineral nitrogen (Liebmann and Keitz, 1965).

It seems that better effects of pond fertilization could be expected if broader investigations into the span of the P : N ratio variation were launched in ponds built on different substrata, that is on sandy, loamy and clay soils, and especially on peat soils because upon these are built large numbers of ponds in many European countries.

1.6 The rôle of lime and carbon dioxide in pond fertilization

Müller (1957; 1961a; 1961b) found no effect of liming on pond fish growth, and Swingle (1947) recorded even a decline in fish growth when lime was administered to pond water showing an alkaline reaction. According to Winberg and Ljachnowicz (1965), liming is unnecessary and even harmful in very alkaline water, above 3 mV/l, because under such conditions, phosphorus is bound into the insoluble calcium phosphate which is deposited on the bottom.

However, liming seems not to be a factor limiting fish growth because in waters of medium mineralization (those with an alkalinity of 2 mV/l which corresponds to 56 mg/l CaO or 560 kg per ha) even with 1,000 kg fish per ha, only about 1.25 percent CaO, or 12.5 kg, is found in the fish, and this amounts to a mere two percent of the total amount of this constituent in the water. Thus it seems that a lime deficiency only occurs in isolated cases, in ponds with exceptionally poorly mineralized water.

On the other hand, the value of adding lime seems to be indisputable for ponds with acid water and bottom sediments.

If we take it that the most general purpose of liming is to increase the alkalinity of the water, in other words to raise the bicarbonate content, then this can only be achieved in the presence of free carbon dioxide by the following reaction:

$$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$$

The alkalinity of the water cannot be raised by the addition of $CaCO_3$[1] unless carbon dioxide is liberated in the course of decay of organic matter. The increase in alkalinity of the water proceeds much faster when slaked lime is used in the presence of dissolved carbon dioxide.

If slaked lime is administered above the carbon dioxide surplus capacity, this may instead of increasing the alkalinity produce its decline due to the deposition of calcium carbonate, which is insoluble, in the following reaction:

$$Ca(OH)_2 + Ca(HCO_3)_2 = CaCO_3 + 2H_2O$$

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[1] i.e. not above 15 ppm in $CaCO_3$ (This solubility of $CaCO_3$ in water at 20°C)

Therefore, alkalinity depends above all on the amount of free CO_2 in water. Carbon dioxide in water is derived from organic matter decay processes. For this reason, the liming of ponds poor in organic sediments or organically unmanured produces no effect.

The role of liming in phosphate and nitrogenous fertilization consists in neutralizing the acid reaction of the bottom sediments. Neutralization of sediments weakens the phosphorus ion bond, thereby facilitating the passage of ions into the water. The acid reaction of the environment holds back the micro-biological processes of ammonification, nitrification and the fixation of free nitrogen. Thus liming produces accelerated circulation of nitrogen and its faster action.

Liming speeds up the decomposition of organic matter and thereby the exuding of CO_2 from the bottom sediments. Moreover, it stimulates the development of microflora, an important food item for invertebrate larvae.

One of the chief objectives in liming ponds is to reinforce the buffer system of the water. This system consisting of CO_2 - HCO_3 - $CaCO_3$, and designed to prevent fluctuations in the pH of the water beyond the lethal limits for fish, is still relatively little known. Further research is required in particular into the rôle of carbon dioxide, which is, according to Maucha (1958), also an agent limiting phytoplankton development.

When the pH of the water is high due to the assimilation processes of plants in ponds fertilized with ammonia-derived nitrogen, a marked concentration of NH_4 ions, strongly toxic for fish, may take place. Such situations are especially dangerous for the postembryonic stages of carp.

1.7 The effect of nitrogenous fertilizers on fish

1.7.1 Type of nitrogenous fertilizer

Scheuring and Leopoldseder (1934) have shown that ammonium fertilizers are more toxic than nitrates. For young carp over 7 cm long the lethal concentration of ammonium sulphate (death within six hours) was 0.03 percent at pH 7.47, but of sodium nitrate it was 2 percent at pH 7.58.

1.7.2 Species and size of fish

The toxic action of fertilizers on carp depends not only on fish size but also on type of scale cover (Wolny, 1964). The fast growing mirror carp, between the time of hatching and growing to 5 cm in body length, is found to be more sensitive to nitrogenous fertilizers than is the slow growing scaleless carp. If percentage mortality be taken as the criterion of toxicity, the most toxic treatment appears to be ammonia liquor applied at the rate of 15 kg/ha N every three days, next ammonium sulphate and least toxic urea. Carp fry above 5 cm long are found to be resistent to a concentration of 2 mg/l N of the above named fertilizers. Therefore, in addition to the proper choice of fertilizers for ponds stocked with carp at different ages, no less important is the method of administering fertilizers, to exclude the possibility of fish running into a lethal concentration zone. The same largely applies to nursery ponds, especially fry ponds stocked with fish a few days old which are exceptionally sensitive to any environmental changes. Swingle and Smith (1938) and Smith and Swingle (1938) offset the toxic action of ammonium sulphate by extra fertilization with basic slag, in place of superphosphate which acidifies the environment.

1.7.3 Physico-chemical properties of water

Soft water with a weak buffer action stimulates the toxicity of ammonia (Schäperclaus, 1961). A rise in temperature has an equally stimulating effect. At Zabieniec experiments showed that a concentration of 50 mg NH_4OH per litre was lethal for young carp individuals weighing 50 g after 30 minutes when the water temperature was 17°C, but in the event of a temperature rise to 23°C, death took place within 13 minutes.

1.8 The effect of the fish-rearing method on the circulation of mineral salts and effectiveness of fertilization

1.8.1 Stock density

The maximum increment in carp per unit area takes place, according to the curve of Nordquist (1928), at an optimum stock density for a given pond type. Optimum stock abundance stimulates carp to feed on the bottom (Gurzęda, 1965). Should the stock density become unduly low or high, the proportion of bottom fauna in carp food diminishes in favour of zooplankton. There is therefore a clear correlation between stock abundance, fish crop, and the ratio of bottom fauna to zooplankton in carp food. The most intense penetration of the pond bottom takes place at optimum fish abundance. The constant stirring of bottom sediments by fish seeking chironomid larvae accelerates the mineralization of organic matter and the circulation of nutrient salts.

It seems that the determination of the fertilizer requirements under conditions of optimum stock density at which the maximum growth of fish is reached, may provide more unbiassed criteria for estimating the action of fertilizers on primary and secondary production. In the latest investigations by Winberg and Lyakhnovich (1965), Kuzhmicheva (1965) and others, the secondary production is understood first and foremost as animal plankton. However at optimum stock density the plankton is of much less importance than bottom fauna since the latter is the main food of carp (Gurzęda, 1965).

1.8.2 Agrotechnical measures

Agrotechnical operations on the bottom of the pond are designed to remove vascular plants and to neutralize the sour silt. The clearing of rooted flowering plants, mosses and Characeae from the bottom determines the efficacy of pond fertilization.

1.8.3 Periodical drainage

Periodical drainage of the pond bottom as borne out by the investigations conducted by Danielewski (1965), results in the mineralization of organic compounds. During the winter drainage period, the mineral nitrogen content in bottom sediments made up of phytoplankton increased by 142.2 kg/ha, as against a decrease of this constituent by 18.5 kg in ponds filled throughout the winter.

1.8.4 Technique of fertilizer administration

Doses of nitrogenous fertilizers administered at seven to ten day intervals are recommended by nearly all writers (Wróbel, 1962; Danielewski and Włodek, 1962; Wolny, 1964; Janeček, 1963; Winberg and Ljachnowicz, 1965). The number and concentration of nitrogen doses depends on the pond category. Fry ponds at Zabieniec are fertilized at three day intervals, and the nitrogen concentration varies between 1 and 1.5 mg per litre. The last dose is given a week before the pond is fished.

Fingerling ponds are fertilized once a week up to the end of August. Fertilization of yearling and commercial ponds begins fourteen days before stocking and ends in mid-August. Nitrogen concentration is kept within the limits of 1 to 2 mg/l. Phosphorus fertilizers are administered every two weeks or even once a month.

2 MINERAL FERTILIZATION OF PONDS

The conditions for autochthonous synthesis of organic matter, which takes place in aquatic plants, chiefly phytoplankton are improved through mineral fertilization (Winberg and Ljachnowicz, 1965).

2.1 The efficacy of phosphate and nitrate fertilizers used separately

The effect of sole administration of mineral phosphorus fertilizers on fish growth was investigated between 1913 and 1949 in the Experimental Pond Station at Wielenbach (Germany, Federal Republic). Superphosphate was administered at a rate of 25 to 30 kg/ha P_2O_5 in two doses, the first applied to the bottom before the spring filling of the ponds, and the second, in water, usually in May. The increased crop, on an average over a number of years, was 72 kg/ha (Demoll, 1925; Probst, 1950). Thus, 0.4 kg P_2O_5 or 2.3 kg superphosphate, went into 1 kg increment of carp weight.

The high efficiency of phosphorus fertilization is limited, however, to a specified level. As demonstrated by Schäperclaus (1961), a further two or threefold increase of superphosphate, to the level of 75 kg/ha P_2O_5, would produce a violent increase in superphosphate consumption to 12 to 15 kg per 1 kg increment of fish weight.

The disproportion between the effect in regard to fish weight increment and the increased superphosphate doses shows that it is not only phosphorus that limits the increase in fish production under conditions of exclusive phosphoric fertilization.

Neither does exclusive nitrogen fertilization, as borne out by the experiments of Winberg (1958) give satisfactory results. In his experiments nitrogen consumption was as high as 7 to 12 kg 35 percent Norway saltpetre per 1 kg of fish weight increment. Under the same conditions but with the addition of superphosphate, seven times as great utilization of Norway saltpetre was obtained.

2.2 The efficacy of combined nitrate-phosphate fertilization

The theory of nitrogenless fertilization advanced by Demoll (1925), as well as the practical indications consequent upon it, have been subject to a profound evolution resulting from limnological researches especially during the past fifteen years.

Several types of ammonium fertilizers in combination with phosphates have already found wider uses, and the development of other types is at the stage of experiment and research carried on mainly by fisheries institutes in a number of countries.

It seems that the fertilizer selection method for various pond types, as well as the method of determining optimum doses in experimental ponds, could be successfully supplemented, in view of the inadequate number of ponds available, by the use of tiny plots made of plastic foil and mounted on a portable scaffold (Janeček, 1963). This plot method may advance the solution of the problem of choice of fertilizers suitable for different soils and climatic conditions.

Wider uses in pond practice have up to the present provided information about the following fertilizers.

2.2.1 Norway saltpetre

Norway saltpetre, NH_4NO_3 contains 20 percent pure nitrogen in the ammonium form and 15 percent nitrogen in the nitrate form. The microbiological investigations by Rodina (1958) have contributed, among other things, to the widespread use of this fertilizer, mainly in the Soviet Union. They showed that Phytoplankton, chiefly blue-green algae, developed quickly under the action of the fertilizer. The development of denitrification bacteria is slowed down under the favourable conditions thus created. Since aquatic plants in general assimilate nitrogen more readily in the ammonium form Norway saltpetre has physiologically weak acidic properties.

The experiments conducted by Winberg (1958) in the "Shemetevo" Breeding Centre in Byelorussia revealed a three- to fourfold increase of carp production in ponds fertilized with nitrogenous-phosphate fertilizers. To obtain 1 kg increment in fish, 1.47 kg 35 percent Norway saltpetre and 2 kg 16 percent superphosphate were utilized. In a region further to the south, Feldman, Prosianyj and Suchowij (1961) obtained between 79 and 290 kg/ha gain in weight, using exclusively nitrogenous-phosphate fertilizers at the rate of 0.65 to 2.33 kg superphosphate and 0.41 to 1.67 kg Norway saltpetre per 1 kg weight increment in carp.

Particularly high fertilizer doses were employed by Mamontowa (1961) for ponds in the vicinity of Moscow. Using 730 kg/ha superphosphate and 1,350 kg/ha Norway saltpetre, she secured a three to three-and-half-fold increase in natural growth, and in individual cases the gain in weight came to as much as 799 kg/ha.

At these maximum doses, 1.64 kg superphosphate and 3 kg Norway saltpetre went into 1 kg carp growth.

It seems, however, that at such a high nitrogen concentration oxygen deficiencies, dangerous to fish, may occur at night under conditions of intense phytoplankton blooms.

In the experiments of Ljachnowicz (1963), the superphosphate dose was 400 kg/ha and that of Norway saltpetre 800 kg/ha. The fertilizers were administered to the water in small lots throughout the growth season. The weight increment of fish came to 400 kg/ha. The mean consumption of fertilizers per 1 kg carp growth was 0.67 kg N and 0.25 kg P_2O_5.

The cost of fertilizers per 1 kg of fish weight increment was one-third that of the fodder that would be required to produce the same gain in weight.

The annual demand for Norway saltpetre and superphosphate and the effects of fertilization obtained in various regions of the Soviet Union are given by Winberg and Ljachnowicz (1965). The estimated annual fertilizer demands ranged from 350-450 kg/ha saltpetre and 300-400 kg/ha superphosphate in north Europe and Siberia, to 700-1,000 kg/ha saltpetre and 600-800 kg/ha superphosphate in south Europe. The carp yields with fertilization ranged from 200-300 kg/ha (compared with 70-80 kg/ha from unfertilized waters) in north Europe and Siberia, to 600-700 kg/ha (compared with 220-250 kg/ha unfertilized) in south Europe.

2.2.2 Ammonium sulphate

Ammonium sulphate, $(NH_4)_2SO_4$, containing 20 percent nitrogen is one of the most widely used fertilizers in the U.S.S.R., Poland, Rumania, Yugoslavia, Germany (eastern), Czechoslovakia and elsewhere.

Ponds fertilized with ammonium sulphate promptly give rise to phytoplankton blooms. The stimulating effect of this fertilizer on bottom fauna was ascertained by Zuntz (1919) and on the extended development of zooplankton over the season by Schäperclaus (1966). Bank (1959) demonstrated that fish grow better in ponds fertilized with ammonium sulphate.

It follows from the investigations on ammonium sulphate, ammonia liquor and urea, conducted by Wróbel (1962) in Golysz and Landek experimental fish farms (southern Poland) situated on loamy soils, that individual fertilizers act differently on the chemical composition of water. The primary production of phytoplankton was doubled at 50 kg/ha N and showed more than a threefold increase at 70 to 85 kg/ha N. Ammonium sulphate produced the least variation in the primary production of phytoplankton. In control ponds, the oxygen output could not meet the demand.

The ammonium nitrogen concentration delivered in the form of ammonium sulphate or ammonia liquor, about 1 mg N-NH_4/1, used to drop to the level prior to fertilization in no more than four to five days. If after applying the fertilizers cloudy weather set in with a drop in temperature, almost invariably nitrites used to appear and the nitrate content would increase. Since in the third year of the experiment, Wróbel recorded a clear decline in fish growth increments, he considered that ammonium sulphate should not be used as fertilizer because most likely a deposition of sulphates takes place.

In the experimental ponds at Zabieniec, which are on sandy soil, a well-marked decline in young carp production was observed even after a year in ponds fertilized with ammonium sulphate at the rate of 15 kg N/ha every three days. Two-year old carp grew 17 percent less on ammonium sulphate than they did on ammonia liquor.

Janeĉek (1963) recorded in the experimental ponds of the Fisheries Institute at Vodniany a 7 percent lower carp increment in plastic-foil plots fertilized with ammonia liquor than in those fertilized with Norway saltpetre.

It is possible that the considerably higher calcium content in Israelian pond waters (Hepher, 1962), compared with waters on the European continent, more effectively eliminates the adverse after-effects of ammonium sulphate on the fish crop.

2.2.3 Ammonia liquor

Ammonia liquor, NH_4OH, containing 20 percent nitrogen, has been in use in some European countries just a few years. The nitrogen contained in ammonia liquor rapidly and strongly stimulates the development of phytoplankton, green algae in particular (Massalski, unpubl.). Ammonia liquor used by Wróbel (1962) in his experiments at the rate of 150 l/ha had only a slight effect on the pH, raising it from 7 to 7.6. The relatively better result of fertilization of the ponds at Zabieniec with ammonia liquor during the cool summer of 1965 was probably related to the reduced toxicity of NH_4 ions at lower temperature. However, in the absence of systematic observations over many years on ammonia liquor fertilization under European climatic conditions, it is impossible to draw as far-reaching conclusions as in the case of the nearly forty-year long investigations on superphosphate (Mortimer, 1954).

Ammonia liquor as fertilizer finds an ever wider application on fish farms. An interesting experiment with ammonia liquor used for fertilizing peaty ponds was made by Mints and Khairulina (1965). About a dozen tons of peat were soaked in ammonia liquor containing 0.9 percent ammonia nitrogen (NH_3) and 15 kg of superphosphate was added per ton of peat. The peat thus treated was transferred in part to the bottom of a pond and after flooding it, another six doses of the treated peat were distributed on the water. Altogether 12.7 tons peat per ha were administered throughout the season. In terms of nitrogen, ammonia liquor consumption was 40.9 kg per ha. The control ponds received 210 kg/ha N in the form of Norway saltpetre.

An examination of the biological activity of the peat pond bottom showed 0.95 mg CO_2/100 g peat. After administering the treated peat, the biological activity rose to 2.4 mg CO_2/100 g. Moreover, the amount of phosphates, nitrates and ammonia in the water increased threefold.

The increased biological activity of the peaty pond bottom was obtained through the bonding of humic acids with ammonia into soluble ammonium compounds. These compounds are reported to stimulate the growth of plants and improve the soil structure. Moreover, ammonia liquor sets in motion the activation of the nitrogen contained in peat.

Since the market price of ammonia liquor is half that of ammonium sulphate, the question arises whether this form of ammonia nitrogen, notwithstanding its toxic action on carp hatchlings and the restricted possibilities of using it in soft waters showing weak buffer action, has any prospects for wide use in practice. The above-mentioned adverse characters are offset by a rapid and high primary production which is by no means unimportant in the European climate marked by a relatively short season of carp growth and only a small number of days over the year with temperature around 25°C.

The action of acidic ammonium carbonate and urea on the pond environment has been the subject matter of experiments carried on now for several years. These fertilizers are bicomponent, as apart from nitrogen they contain carbon dioxide which, like nitrogen, when at minimum value, limits phytoplankton development (Maucha, 1958).

2.2.4 Acidic ammonium carbonate

Acidic ammonium carbonate (NH_4HCO_3) contains 16 percent nitrogen and 50 percent carbon dioxide. Unlike ammonium sulphate, this salt is not physiologically sour as fertilizer since both its constituents (N and CO_2) can be readily assimilated by aquatic plants. Experiments with acidic ammonium carbonate carried on in the period 1963-1965 at Zabieniec revealed a number of favourable properties of this compound which had not hitherto been used as pond fertilizer.

The investigations by Danielewski (unpubl.) revealed a number of changes favourable for fish in the chemical composition of water. The alkalinity of water and carbonate hardness increased under the action of acidic ammonium carbonate. The reinforcement of the buffer system of water under the action of carbon dioxide held in check the biological decalcification of water, which occurred in the most acute form when using ammonia liquor as fertilizer. The relatively small variation of oxygen and pH value of water was, no doubt, linked with the improved buffer system.

Investigations into the species composition of phytoplankton (Massalski, unpubl.) showed that almost a mono-culture of green algae (Protococcales 92 percent of the total cell abundance) developed, whilst simultaneously the number of diatoms decreased to one-quarter. This result corresponds with the investigations by Lund (1965) who ascertained a mass development of diatoms in soft waters. Acidic ammonium carbonate proved to be, therefore, a quick-action fertilizer, which is of major importance for carp fry production under the system of Dubisch which involves a double transfer of fish from the spawning pool, first to a fry pond and then to a fingerling pond, so the ponds are only in use for short periods of one to three months. Ichthyological research revealed (Wolny, 1965) that NH_4 action from acidic carbonate was harmless even for hatchlings a few days old.

A doubled natural increment in carp fry was obtained with the action of acidic ammonium carbonate in 1964. The extra natural growth was 234 kg per ha, which means that 1.17 kg carp was gained per 1 kg N, compared with 0.99 kg per 1 kg N contained in ammonium sulphate. The beneficial effect of ammonium carbonate on oxygen conditions was also manifest in ponds in which fry were intensely fed on sorghum. The oxygen level at 1,098 kg fry per ha was even slightly higher there than in unfertilized ponds with a considerably lower fish production (692 kg/ha).

Microbiological investigations of the near-bottom water layer in ponds fertilized with ammonium carbonate in which the carp fry were supplied with fodder, showed that the abundance of bacteria per milli-litre water was smaller than in similar ponds fertilized with ammonium sulphate, and producing less fish (Zolnierkiewicz, unpubl.). Possibly green algae (Protococcales) in decomposing autolytically (Winberg and Ljachnowics, 1965) failed to produce a medium for an appreciable number of bacteria. The results of chemical analysis which showed a higher mineral phosphorus level in pond water fertilized with ammonium carbonate, pointed to a decomposition of green algae without the agency of bacteria, and to the liberation of mineral phosphorus through autolysis.

Further investigations should answer the question whether acidic ammonium carbonate is as good for fertilizing ponds designed for older, two to three-year old carp as it is for fry ponds.

2.2.5 Urea

Urea, $(NH_2)_2CO$, containing 45 to 46 percent pure nitrogen represents a highly concentrated fertilizer with nitrogen in the amide form. The ammonification of urea in water proceeds along bacterial and enzymatic lines. Under the action of the urease it is hydrolyzed to ammonia and carbon dioxide. Since aquatic plants assimilate both ammonia and carbon dioxide, urea can be considered a physiologically neutral fertilizer; it is a bicomponent fertilizer, and contains 78 kg carbon dioxide per 100 kg fertilizer. It still remains open for research to determine at what concentration urea as a chemical compound begins to be toxic for various age groups of fish and invertebrates.

The usefulness of urea for pond fertilization has not yet been sufficiently studied. Wróbel (1962) considers it to be a slow-action fertilizer because in his investigations phytoplankton first appeared in the latter part of the growth season. Since a marked increase in zooplankton occurred in the first part of the season, he suggests the use of a mixture composed of the fast ammonia liquor and the slow urea.

The experiments made at Zabieniec between 1963 and 1965 confirmed the slow action of urea on phytoplankton development. Investigations into the species composition of phytoplankton (Massalski, unpublished) showed that urea held back the development of diatoms. The toxic action of urea on carp hatchlings at 15 kg/ha N resulted in the effect of fertilization being 20 percent lower than that in control ponds (Wolny, 1964). But in the following years, while maintaining the same conditions of the experiment, an ever better fish increment was obtained, fish productions in 1964 and 1965 being more than 24 and 38 percent respectively over those in control ponds. Economic considerations are also encouraging to continued research on urea as it is a cheaper nitrogenous fertilizer than, say, ammonium sulphate, and in addition, it contains carbon dioxide which also stimulates phytoplankton development.

3 ORGANIC FERTILIZATION OF PONDS

Organic fertilizing is instrumental in direct enrichment of the pond with allochthonic substances as a ready food for zooplankton and bottom fauna, and as an indirect source of nutrient salts and carbon dioxide. The scale on which it is possible to step up fish production chiefly through manuring is well exemplified by Trebon, one of the largest fish farms in Czechoslovakia (Dejdar, 1956). Here, fish production between 1927 and 1935 increased from 310 to 1,060 tons per year, whilst fodder consumption was reduced. On the other hand, the consumption of barnyard, pig and poultry manure, as well as compost, increased from 1,425 to 5,600 tons. Superphosphate fertilization also increased from 38 to 925 tons, and liming from 290 to 1,797 tons.

Among the forms of manure used most frequently in European countries are the following:

3.1 Barnyard and pig manuring

Mowczan (1948) managed to obtain a gain in fish growth of from 50 to 205 percent in barnyard-manured, as against unmanured ponds. He recommended repeated administration of this manure or compost, which should be placed in small heaps along the pond dyke. Depending on the quality of manure or compost, the amount required per individual carp increment varies between 18 and 70 parts of the fertilizing agent.

Havlena (1956) using between 1.8 and 10.0 tons per ha of pig manure obtained an extra growth of fish of between 31 and 417 kg/ha, i.e. by 9 to 167 percent. The calculated average individual growth came to 2.5 to 3 kg carp per 100 kg manure. The optimum dose of pig manure is 5 tons per ha (Bena, 1957; Stedronsky and Pekar, 1958; Vaclavik, 1957; et al.).

Woynarovich (1956a; 1956b; 1956c; 1957) designed an original device, a "manure cannon" for uniform distribution of pig manure over the pond surface. Manure should be oxidized on the pond surface as quickly as possible because once it has settled down at the bottom under almost oxygen-less conditions, the decay of organic matter proceeds at a much slower pace. A manure dose of four to five tons per ha under conditions of intense photosynthesis produces no oxygen deficiency.

3.2 Pond manuring with town sewage and foodstuff-industry wastes

Munich city sewage effluents, mechanically purified and diluted with pure water in the proportion of 1:3 or 1:5 served as an organic manure for ponds (Demoll, 1924). The annual growth increment in carp varied between 400 and 600 kg/ha.

Sewage effluents of Berlin, biologically purified by the filtration field method when brought into ponds at Schönerlinde, produced a natural growth of carp at the rate of 800 to 900 kg/ha (Schäperclaus, 1961).

Town sewage effluents of Kielce (central Poland) purified by the activated sludge process and introduced into ponds without being diluted made an excellent medium for phytoplankton which was composed chiefly of *Scenedesmus* and *Chlorella* algae. The natural fish growth under these conditions came to as much as 1,300 kg/ha (Wolny, 1962). The natural food of carp consisted mainly of Chironomidae (55 percent), and Crustacea (30 percent).

The method of utilizing wastes from the foodstuff industry in fish ponds was developed by a group of Czechoslovak investigators, namely for

- dairy wastes (Pytlik and Svec, 1954)
- sugar-mill wastes (Pytlik, Votava and Benes, 1954)
- slaughter-house wastes (Pytlik and Dusek, 1956; Pytlik, 1957)
- starch-mill wastes (Pytlik, *et al.*, 1957)

Unprocessed sewage and wastes deposited in ponds are treated with a lime dose of about 5 tons/ha. The fish crop from this type of effluent averages 500 to 600 kg/ha.

Cerny (1961) reported that he obtained an increment of 748 kg in natural growth of carp in a pond fed with starch water from one of the mills in Austria. The high rate of survival recorded was evidence that both physical and chemical agencies formed a favourable set-up in the above pond.

3.3 Organic manuring of ponds by combined domestic-duck and fish breeding

The method of duck breeding in carp ponds developed by Probst (1934), has been widely used on fish farms in several European countries during the past twelve years or so. Duck breeding in ponds has developed in particular in Germany (Eastern), where carp and duck production are almost on the same level (Menzel, 1965), and also in Czechoslovakia where domestic-duck breeding in carp ponds comes to several million individuals yearly. The presence of flocks of ducks in ponds brings about essential changes in both phyto and zoocenoses. In a pond with a flock of duck of about 200 individuals per ha, *Ceratium hirudinella* and *Dinobryon divergens* were predominant in phytoplankton (Sosnowska, 1956), whereas in a pond fertilized with superphosphate, the blue algae *Anabaena spiroides* and *Microcystis aeruginosa* predominated. Diatoms predominated in the control ponds.

The optimum abundance of a flock of duck per ha varies within fairly broad limits depending on the character of the environment. Carp growth in ponds with ducks may increase two to fivefold, up to 500 kg/ha, under favourable conditions (Frček, 1957; Janeček, 1958).

3.4 Organic manuring of ponds with fish excrement and unconsumed fodder remains

This is an atypical form of organic manuring of ponds, which cannot be judged easily in terms of fish growth but can only be surmised from indirect indices, either biological, for example by weight increase of chironomid larvae (Wójcik-Migala, 1965) or a greater biomass and individual size of invertebrate fauna consumed by carp (Gurzęda, 1965), or from abiotic indices, such as a violent decline in oxygen to the minimum required by carp (Szpet and Feldman, 1959). Oxygen requirements may thus limit the fertilization of the water by these means.

4 PLACE OF POND FERTILIZATION IN THE ECONOMIC MODEL OF POND FISH PRODUCTION

In the light of the facts presented here the question should be raised as to what place pond fertilization holds in the economic model of pond fish production.

To sum up the above considerations, one may say that pond fertilization holds a key position along the road to the development of a system of multi-stage intensification of pond productivity. On the one hand, mineral fertilization improves oxygen conditions in the water, and on the other, it helps to reduce fodder consumption per carp production unit, as it improves the ratio of natural to artificial feed.

5 REFERENCES

Backiel, T., Współczynnik pokarmowy i termiczny w produkcji karpi. *Roczn.Nauk.rol.*,
1964 *(B)*, 84(2):363-72 (English and Russian summaries)

Bank, O., Phosphordüngung und ihre Anwendung. *Fischbauer*, 10:1-3
1959

Bena, J., Použiti organického hnojiva vstahum pro hno jenirybníku. *Sborn.čsl.Akad.*
1957 *zeměd.Věd (živ.Výr.)*, 5:381-84 (Russian and German summaries)

Braginskii, L.P., Biologicheskie ispytania potrebnosti planktona prudov lesostiepi
1955 Ukrainskoi SSR v mineralnykh udobreniakh. *Sborn.nauch.Rab.ukr.nauch-issled.*
Stant.Ryb., 1:47-57

__________, Isledovanie "potrebnosti" prudovogo fitoplanktona v azotie, fosforie i
1958 kalii metodom biologicheskikh ispitanii. *Sborn.nauch.Rab.ukr.nauch-issled.*
Stant.Ryb., 3:15-28

__________, O sootnoshenii mezhdu sostavom prudovogo fitoplanktona i proiavleniem
1961 ego "potrebnosti" biogennykh elementakh. *In* Sbornik Pervichnaia
produktsiia morei i vnutrennykh vodoemov, Minsk, pp. 139-47

Cerny, A., Über die Eutrofierung eines Teiches durch Abwässer der Kartoffelstärke-
1961 fabrikation. *Verh.int.Ver.Limnol.*, 14:1086-90

Danielewski, S., Mineralizacja osadów dennych w okresie zimowego osuszania stawów.
1965 *Roczn.Nauk.rol.(B).*, 86(2):341-59 (English and Russian summaries)

__________, Zmienność składu chemicznego wody w stawach pod wpływem nawożenia
1966 azotowego. (unpublished MS)

Danielewski, S. and S. Włodek, Ocena efektu nawożenia stawów woda amoniakalna i
1962 siarczanem amonu w 1961 roku. *Gosp.rybna.*, 2:4-8

Dejdar, E., Ertragssteigerung der tschechoslowakischen Teiche durch mineralische und
1956 organische Düngung. *Dtsch.Fisch-Ztg.*, 3(11):342-5

Demoll, R., Die Reinigung von Abwassern in Fischteichen. Handb.Binnenfisch.Mitteleur., 6(2)
1924

_____________, Teichdüngung. Handb.Binnenfisch.Mitteleur., 4(1):53-160
1925

Feldman, M.B. and A.V. Sukhovii, Vlinianie mineralnykh udobrenii na gidrokhimicheskii rezhim prudov. In Pervichnaia produktsiia morei i vnutrennykh vodoemov, Minsk, pp. 165-72
1961

Feldman, M.B., W.S. Prosianyi and A.V. Sukhovii, Rozrobka i obgruntovaniia ratsional'nogo metodu vnieseniia u stavi mineralnykh dobriv. Nauk.Tr.ukr. nauk-doslid.Inst.rib.Gosp., 14:59-70
1961

Frček, M., Vliv chovy kachen na přirozenou výrobnost rybníku. Čsl.Rybářst., 6:84-5
1957

Gurzęda, A., Wpływ paszy na odżywianie sie narybku karpi. Roczn.Nauk.rol.(B), 86(2): 205-82 (English and Russian summaries)
1965

Havlena, F., Zpusob a význam použiti hnojiv z velkovýkrmen vepřu s hlediska rybářského. Sborn.čsl.Akad.zeměd.Věd (živ.Výr.), 5:385-94 (Russian and German summaries)
1956

Hepher, B., Ten years of research in fish ponds fertilization in Israel. 1. The effect of fertilization on fish yields. Bamidgeh, 14:29-38
1962

Janeček V., Jr., Výsledky srovnávacích pokusu s minerálnimi dusikatými hnojiví v novém typu experimentálního pracoviště. Práce VURH Vodňany, 3:7-24 (English Russian and German summaries)
1963

Janeček, V. and V. Janeček, Využiti chovy kachen k prohnojování menších rybníku. Sborn.čsl.Akad.zeměd.Věd (živ.Výr.), 4:311-20 (Russian and German summaries)
1958

Kuźmicheva, V.I., Pervichnoe deistvie mineralnykh udobrenii v vyrostnykh prudakh. Trudy vses.nauchno-issled.Inst.prud.kyb.Khoz., 13:131-8
1965

Liebmann, H. and G. Keitz, 50 Jahre Teichwirtschaftliche Abteilung Wielenbach der Bayerischen Biologischen Versuchsanstalt. München. Festschrift: Der Fisch in Wissenschaft und Praxis.
1965

Liakhnovich, V.P., efektivnost' udobrenia prudov. In desiataia nauchnaia konferentsiia po vnutriennim vodoemam Pribaltiki., pp.:127-8
1963

Lund, J.W.G., Chemical analysis in ecology illustrated from lake district tarns and lakes. 2. Algal differences. Proc.Linn.Soc.Lond., 16:165-71
1956

_____________, The ecology of freshwater phytoplankton. Biol.Rev., 40:231-93
1965

Mackareth, F.J., Chemical analysis in ecology illustrated from lake district tarns and lakes. 1. Chemical analysis. Proc.Linn.Soc.Lond., 16:159-64
1956

Mamontova, L.H., Ob uvelichenii ryboproduktivnosti prudov vneseniem raznykh doz mineralnykh udobrenii. In Pervichnaia produktsiia morei i vnutrennykh vodoemov, Minsk, pp. 173-8
1961

Massalski, A., Zmiany ilościowe i jakościowe fitoplanktonu w przesadkach l.,w 1963 roku-Instytut Rybactwa Środladowego Zakład Gospodarki Stawowej, Żabieniec. (Unpublished MS)

Maucha, R., Zur Frage der Produktionsbiologie der Seen. Verh.int.Ver.Limnol., 8:212-6
1958

Menzel, H.U., Jahresbericht 1964 über die Produktion der Binnenfischerei der Deutschen
1965 Demokratischen Republik. Dtsch.Fisch.Ztg., 12(4):97-113

Mints, A.G. and E.N. Khairulina, Novyi sposob udobrenia prudov postroennykh na
1965 torfianikh vyrabotkakh. Trud.vses.nauchno-issled.Inst.prud.ryb.Khoz.,
13:113-30

Mortimer, C.H., Fertilizers in fishponds. Fish.Publ.,Lond., (5):155 p.
1954

Mowczan, B.A., Ekologicheskie osnovy intensifikatsii rosta karpa. Kiev, 349 p.
1948

Müller, W., Die Teichversuche des Jahres 1956 in Königswartha. Dtsch.Fisch-Ztg.,
1957 4:10-5

___________, Der Einfluss der Kalkung auf das Wasser in der Teichwirtschaft
1961a Königswartha im Jahre 1960. Dtsch.Fisch-Ztg., 8:183-7

___________, Ursachen für das Ausbleiben einer Kalkungswirkung in Karpfenteichen.
1961b Verh.int.Ver.Limnol., 14:713-7

Nordquist, H., Nyare rön på dammhushalleningens område. Sverig.Fisk.Foren., (1)
1928

Priwolnjew, T.I., Die Atmung in der Ontogenese der Fische bei verschiedenem partiellem
1957 Sauerstoffdruck. Z.Fisch., 6(8):597-604

___________, Die Atmung in der Ontogenese der Fische bei verschiedenem partiellem
1958 Sauerstoffdruck. Z. Fisch., 7(7/8):629

Probst, E., Teichwirtschaft und eflügelzucht in ihren Wechselbeziehungen. Handb.
1934 Binnenfisch.Mitteleur., 4(1):161-82

___________, Teichdüngung. Die Bedeutung des Phosphors. Allg.Fisch.Ztg., 89:191-4
1950

Pytlík, R., Oczyszczanie ścieków domowych oraz organicznych ścieków przemyslowych
1957 metoda stawów akumulacyjnych i asymilacyjnych. Biul.Zakl.Biol.Stawow, (5)

Pytlík, R. and K. Dušek, Čištění a využitkování odpadních vod jatek a zavodu masného
1956 prumyslu v asimilačních rybnicich. Sborn.čsl.Akad.zeměd.Věd (živ.Výr.),
4:239-54 (Russian and German summaries)

Pytlík, R. and Z. Švec, Čištění a využitkování odpadních vod mlékárenských v
1954 asimilačních rybnicích. Sborn.čsl.Akad.zeměd.Věd (živ.Výr.), (2-3):177-98
(Russian and German summaries)

Pytlík, R., J. Votavá and V. Beneš, Čištění a využitkování řizkových odpadních vod
1954 cukrovarských v akumulačních rybnicích. Sborn.čsl.Akad.zeměd.Věd (živ.Výr.),
(2/3):337-44 (Russian and German summaries)

Pytlík, R. et al., Akumulační rybník Malikovsky v letech 1953 až 1965. Sborn.čsl.
1957 Akad.zeměd.Věd (živ.Výr.), 5:329-48 (Russian and German summaries)

Rodhe, W., Environmental requirements of fresh-water plankton algae. Symb.bot.
1948 upsaliens., 10(1)

Rodina, A.G., Azotnye udobrenia rybovodnykh prudov i denitrifikatsiia. Trud.Akad.
1958 Nauk.latv. SSR., 7:61-78

Schäperclaus, W., Lehrbuch der Teichwirtschaft. Berlin, P. Parey, 582 p.
1961

__________, Steigerung der Karpfenerträge in Teichen durch Stickstoffdüngung
1966 (N-Düngungsversuche in Kauppa 1965). Dtsch.Fisch-Ztg., 13(1):6-14

Scheuring, D.L. and Leopoldseder, Die Wirkung der wichtigsten Düngersalze auf Fische.
1934 Arch.Hydrobiol.Planktonk., 27

Smith, E.V. and H.S. Swingle, The relation between plankton production and fish
1938 production in ponds. Trans.Am.Fish.Soc., 68:309-15

Sosnowska, J., Zielenice w planktonie stawów rybnych gospodarstwa doświadczalnego PAN
1956 w Landeku. Acta Soc.Bot.Pol., 25(2):203-44 (English summary)

Stangenberg - Oporowska, K., Badania nad chemizmem wód stawów karpiowych Zespoly
1961 Milicz. Polsk.Arch.Hydrobiol., 9:37-157 (Russian and German summaries)

Štědronsky, E., Č. Pekař., Výživa a rust kaprího pludku. Sborn.čsl.Akad.zeměd.Věd
1958 (Živ.Výn), 4:259-80

Stegman, K., Wpływ temperatury środowiska w granicach optimum fizjoloticznego na
1960 wzrost karpia. Zesz.nauk.Szk.glów.Gosp.wiejsk (Zootech.), (1):37-85
(Russian and German summaries)

Swingle, H.S., Experiments on pond fertilization. Bull.Ala.agric.Exp.Sta., (264)

Swingle, H.S. and E.V. Smith, Fertilizers for increasing the natural food for fish in
1938 ponds. Trans.Am.Fish.Soc., 68:126-35

Shpet, G.I. and M.B. Feldman, Kis orodnyi balans karpovykh prudov v sviazi v
1959 intensifikatsiei karpovogo khoziaistva. Trudy Soveshch.Probl.Biol.vnutr.
vod., 4:48-58

Vaclavík, B., Výroba komposty v rybnikářství. Čsl.Rybářst., (1):4-5
1957

Vinberg, G.G., Isledovaniia potrebnosti v mineralnykh udobreniiakh rybovodnykh prudov
1953 BSSR. Uchen.Zap.bieloruss.gos.Univ., 17:207-21

__________, Isledovaniia po efektivnosti mineralnykh udobrenii na opytnykh prudach
1958 prudkhozu, "Shemietovo". Trudy biol.Sta.Ozere Naroch', 1:193-96

Vinberg, G.G. and W.P. Liakhnovich, Udobrenie prudov. Moskva, 268 p.
1965

Włodek, S., Wpływ nawożenia organicznego na nasilenie i obieg materii w zbiornikach
1962 wodnych. Roczn.Nauk rol.(B), 81(2):251-74 (English and Russian summaries)

Wolny, P., Przydatność oczyszczonych ścieków miejskich do hodowli ryb. Roczn.Nauk
1962 rol.(B), 81(2):231-50 (English and Russian summaries)

__________, Produkcja narybku karpi w stawach nawożonych weglanem amonu. Gosp.rybna,
1964 2:20-2

__________, Carp culture. In Fresh water fisheries of Poland. Kraków, Polish
1965 Academy of Sciences, pp. 69-76

Woynarovich, E., Die organische Düngung von Fischteichen in produktionsbiologischer
1956a Beleuchtung. Acta agron.hung., 6:443-74

__________, Das Carbon - Düngung - Verfahren. Dtsch.Fisch-Ztg., 3(2):48-52
1956b

__________, Versuchsergebnisse der Düngung von Fischteichen mit organischen
1956c Düngemitteln in Ungarn. Dtsch.Fisch.Ztg., 3(1):17-9

__________, Bedeutung der Carbondüngung von Fischteichen. Dtsch.Fisch-Ztg.,
1957 4(1):15-6

Wójcik - Migała I., Wpływ narybku karpi na dynamike fauny dennej. Roczn.Nauk rol.(B),
1965 86(2):195-214 (English and Russian summaries)

Wróbel, S., Wpływ nawożenia azotowo - fosforowego na sklad chemiczny wody, produkcje
1962 pierwotna fitoplanktony i przyrosty ryb w stawach. Acta hydrobiol.,Kraków,
2:151-204 (German summary)

Wunder, W., Fortschrittliche Karpfenteichwirtschaft. Stuttgart, 385 p.
1949

Zuntz, N., Historische Enlwicklung der Fragestellung unserer Teichdüngungsversuche.
1919 Z.Fisch.N.F., 4:1-10

Zołnierkiewicz, E., Wpływ nawożenia mineralnego i żywienia ryb na rozwój mikroflory
1965 bakteryjne w stawach karpiowych. Warszawa, Uniwersytet Warszawski.
Katedra Mikrobiologii. (Unpublished MS)

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BENTHIC ORGANISMS OF FERTILIZED AND UNFERTILIZED PONDS IN WINTER 1/

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BENTHIC ORGANISMS OF FERTILIZED AND UNFERTILIZED PONDS IN WINTER

Abstract

Populations of benthic organisms in ponds at Auburn, Alabama, U.S.A. were sampled from December, 1963 through February, 1964. The twelve 0.1-hectare ponds used had been fertilized with either (N-P-K) 8-8-2 or 0-8-2, with necessary controls.

Multiple-plate samplers were used for obtaining samples.

Dry weights of organisms and counts of individual animals were obtained. The dominant groups of animals are listed and their average numbers per square meter given.

The rate of increase of biomass in the samples from ponds that had received 8-8-2 and those that had received 0-8-2 fertilization were significantly greater than those from the ponds that had received no fertilization, but the rates from the 8-8-2 and 0-8-2 ponds were not significantly different from each other. The variations in populations due to depth were not significant.

A comparison of dry weights obtained in winter with previous records of dry weights from samples in summer indicated that the productive capacity in summer was significantly higher than that in winter.

ORGANISMES BENTHIQUES DES ETANGS FERTILISES ET NON FERTILISES EN HIVER

Résumé

Des échantillons de peuplements d'organismes benthiques ont été prélevés dans des étangs à Auburn, Alabama (Etats-Unis), de décembre 1963 à février 1964. Les douze étangs, d'une superficie de 0,1 hectare chacun avaient été fumés soit avec (N-P-K) 8-8-2, soit avec 0-8-2 et avaient fait l'objet des contrôles requis.

Des échantillonneurs à plaques multiples ont été utilisés pour les prélèvements.

Le benthos a été pesé à sec et des décomptes d'organismes individuels effectués. L'auteur donne la liste des principaux groupes d'organismes repérés et le nombre moyen d'individus par mètre carré.

Dans les échantillons provenant des étangs fertilisés avec 8-8-2 et de ceux fertilisés avec 0-8-2, le taux d'accroissement de la biomass était sensiblement égal, mais nettement supérieur à celui des étangs non fertilisés. Les variations de population en profondeur sont insignifiantes.

La comparaison du poids sec des échantillons prélevés en hiver avec des données relatives au poids sec en été indique que la capacité de production est sensiblement plus élevée en été qu'en hiver.

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ORGANISMOS BENTONICOS EN LOS ESTANQUES FERTILIZADOS Y NO FERTILIZADOS EN INVIERNO

Extracto

De diciembre de 1963 a febrero de 1964, se tomaron muestras de las poblaciones de organismos bentónicos en los estanques de Auburn, Alabama, (E.U.A.). Los doce estanques de 0,1 Ha utilizados habían sido fertilizados con (N-P-K) 8-8-2 o 0-8-2, con los controles necesarios.

Para obtener las muestras, se emplearon toma muestras de placas múltiples.

Se obtuvieron el peso en seco de los organismos y los recuentos de los distintos ejemplares de animales. Se da la relación de los grupos de animales dominantes y el número medio de los mismos por m^2.

La tasa de incremento de la biomasa en las muestras correspondientes a los estanques con una fertilización de 8-8-2 y de los que habían recibido 0-8-2 fueron notablemente mayores que la de los estanques que no habían recibido ninguna fertilización. Pero en cambio, no difirieron mucho una de otra la de los estanques con 8-8-2 y 0-8-2. Las variaciones en las poblaciones debido a la profundidad no fueron notables.

La comparación de los pesos en seco obtenidos en invierno con los anteriores datos de peso en seco correspondientes a muestras obtenidas en verano, indicaron que la capacidad productiva en esta estación del año era sensiblemente más elevada que en invierno.

1 INTRODUCTION

Benthic organisms are of great importance in nutrition cycles in fish ponds and their quality and quantity have been used as indications of productivity.

When studying benthos, different kinds of dredges, artificial substrata, and other devices have been employed to collect samples from various types of bottom. The quantities of organisms sampled by these devices provide a measure of the "standing crop". This measurement has usually been considered a poor index of productivity without some indications of the time factors involved in its formation (Ryther, 1956).

To investigate the formation and growth of populations of benthic organisms, Hester and Dendy (1962) developed the multiple-plate sampler. For the organisms that attach themselves to the samplers, this provides protection from fish predation. It thus measures the biomass on the substrata between the plates of sampler, rather than standing crop after predation by fish.

When samplers were hung at a certain depth in the water, the artificial substrata were populated by free-swimming stages of various animals. The bottom-dwelling organisms which burrow in mud and live in or on the bottom deposits at all stages of their life histories could not be sampled by such hanging samplers. To sample this part of the benthos with multiple-plate samplers, a method was needed to place the samplers in contact with the bottom and yet not allow them to sink into the soft mud.

Previous work using multiple-plate samplers for studies on the benthic organisms of experimental ponds in the Auburn University Agricultural Experiment Station, Alabama, had been conducted in summer. The effectiveness of these samplers for study of winter populations and seasonal variations was not known. Information was needed on the composition of winter populations and on the seasonal variation of populations under different conditions of fertility.

Fertilization of pond water to increase fish-food organisms has been practised in many countries, but much still needs to be learned about its effects. In America, Howell (1942) and Gross _et al_. (1946) observed that complete fertilization of pond water could increase the production of bottom organisms. Ball (1949; 1951) found that the volume of fish-food organisms could often be greatly increased by the addition of fertilizer. Neess (1949) discussed the function of bottom soils and the usefulness of fertilizing substances in increasing fish yields. In the brackish-water ponds of Taiwan, Tang and Chen (1957) reported that chemical fertilizer could be used to promote the growth of benthic algae which serve as the main food of the milkfish, _Chanos chanos_.

The effects of summer fertilization on benthic populations in winter have not been studied.

The bottom deposits have important effects on the distribution and abundance of benthic invertebrates. These deposits usually vary according to depth. In Auburn, Alabama, Howell (1942) found that during the drought in November 1940, the numbers of organisms per square metre at depths of 0.15, 0.46 and 0.92 metre were 17,493, 16,707, and 23,528 respectively in fertilized ponds and were 1,173, 5,583 and 2,033 in unfertilized ponds. Curry (1954) concluded that one of the principlal factors affecting distribution of benthic fauna appeared to be bottom type. McIntire and Bond (1962) observed that the benthic organisms in fertilized ponds became abundant initially in very shallow water (0.3 m or less), and built up populations in deeper water more slowly. Nevertheless, very little was known about the effect of depth on winter populations.

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Table I

Total amount of fertilizers applied to ponds from 1959 through 1963, Auburn, Alabama 1/

Ponds and kinds of fertilizers	Kg of fertilizer used per pond					
	1959	1960	1961	1962	1963	Total
F18, F21, F24, F27	0	0	0	0	0	0
F16, F19, F22, F25						
Triple superphosphate	19.0	16.8	17.3	13.4	13.4	79.9
Potassium chloride	3.7	3.7	3.7	2.9	2.9	16.9
F17, F20, F23, F26						
Ammonium nitrate	27.2	27.2	27.2	27.2	27.2	125.0
Triple superphosphate	19.0	16.8	17.3	13.4	13.4	79.9
Potassium chloride	3.7	3.7	3.7	2.9	2.9	16.9

1/ Data from Annual Reports of Auburn University Agricultural Experiment Station, Auburn, Alabama

Table II

Invertebrates present in the samples from multiple-plate sampler in contact with the bottoms of ponds. Auburn, Alabama, December 1963 to February 1964

1. Protozoa
   - *Volvox* sp.
   - *Vorticella* sp.
2. Coelenterata
   - *Hydra* sp.
3. Platyhelminthes
   - *Dugesia* sp.
4. Nematoda
   - *Prismatolaimus* sp.
5. Annelida
   - *Pristina* sp.
   - *Lumbriculus* sp.
   - *Nais* sp.
   - *Naidium* sp.
   - *Chaetogaster* sp.
6. Arthropoda
   - Cladocera
     - *Diaphanosoma brachyurum* (Lievin)
     - *Pleuroxus striatus* Schodler
     - *Alona* sp.
   - Copepoda
     - *Diaptomus* sp.
     - *Macrocyclops* sp.
     - *Bryocamptus* sp.
   - Ostracoda - several spp.
   - Odonata
     - *Chromagrion conditum* (Hagen)
     - *Cordulia shurtleffi* Scudder
   - Trichoptera
     - *Oxyethira* spp.
     - *Oxyethira serrata* Ross
     - *Ochrotrichia* sp.
     - *Oecetis cinerascens* McLachlan
     - *Oecitis eddlestoni* McLachlan
     - *Hydroptila* sp.
   - Ephemeroptera - various species
   - Diptera
     - *Chaoborus* sp.
     - *Corynoneura* sp.
     - *Pentaneura* sp.
     - *Chironomus* (*Synchironomus*) sp.
     - *Chironomus* (*Glyptotendipes*) *lobiferus* Say
     - *Chironomus* (*Ctyptochironomus*) sp.
     - *Palpomyia* sp.
7. Mollusca
   - *Ferryssia* sp.
   - *Gyraulus* sp.

2 MATERIALS AND METHODS

2.1 Ponds

The samples in this study were taken from twelve 0.1 ha earthen ponds, known as F16 to F27, at the Auburn University Agricultural Experiment Station, Alabama. All these ponds had a common water supply from a canal.

During the period of this experiment the water was 0.6 m at the shallow ends of the ponds and gradually increased to a maximum depth of 2.4 m near the drain pipes. The bottoms of these ponds were generally alike, ranging from slightly stiff sandy clay in the shallow edges to soft muddy ooze in the deep waters.

2.2 Previous treatments of ponds

The ponds were constructed in 1940-1941 and were fertilized at an average rate of N-P-K 100-46-36 kg/ha per year from 1942 to 1959. From 1959 through 1963, these ponds were used for fertilization experiments with four replications of three different levels of fertilization: (i) no fertilization, (N-P-K) 0-0-0; (ii) non-nitrogenous fertilization, (N-P-K) 0-8-2; and (iii) "complete" fertilization, (N-P-K) 8-8-2. All ponds were drained in October or November each year and then were refilled. The total amounts of fertilizer applied to these ponds from 1959 to 1963 are listed in Table 1. In 1963, the ponds were not drained. Eight applications of fertilizer were made between 12 March and 17 September, but no further fertilizer was added throughout the period of the study from 7 December 1963 to 28 February 1964.

2.3 Fishes

Each pond was stocked with 250 fathead minnows, Pimephales promelas, (0.63 kg) on 1 March 1963; 375 bluegill, Lepomis macrochirus, fingerlings (0.68 kg) on 4 March; and 25 largemouth bass, Micropterus salmoides, fingerlings on 30 April 1963.

2.4 Sampling and analysis

A total of 288 samples were collected between 7 December 1963 and 28 February 1964. Sampling for the organisms was carried out with two types of multiple-plate sampler.

Multiple-plate samplers supported by frames to ensure contact with the bottom (Fig 1) were used for sampling the organisms in or on bottom deposits. They consisted of two plates of tempered hardboard (masonite), 0.23 cm thick and 7.62 cm^2 separated by a 2.54 cm^2 plate of the same material. The sampler was attached in a vertical position to the frame with a rubber band, and by a nylon cord to a stake driven into the pond bottom.

In each experimental pond, stations at depths of 0.6 m, 1.2 m, and 2.4 m were marked with wooden stakes inserted into the bottom. The samplers were set and raised from a boat. At each station, two samplers were placed on the bottom near the stake.

All samplers were exposed for three weeks. In recovering the samplers, each was pulled up gently, and carefully enclosed in a plastic bag before bringing it out of the water. They were transported to the laboratory where the contents were sorted into pans. The organisms on the edges and the protected inner surfaces of the plates were scraped off with a spatula. The two samples from the same station were combined and concentrated in the "bucket" of a Wisconsin type plankton net equipped with No. 20 standard silk bolting cloth. Concentrates were examined under a binocular microscope. The sample was preserved in 10 percent formalin.

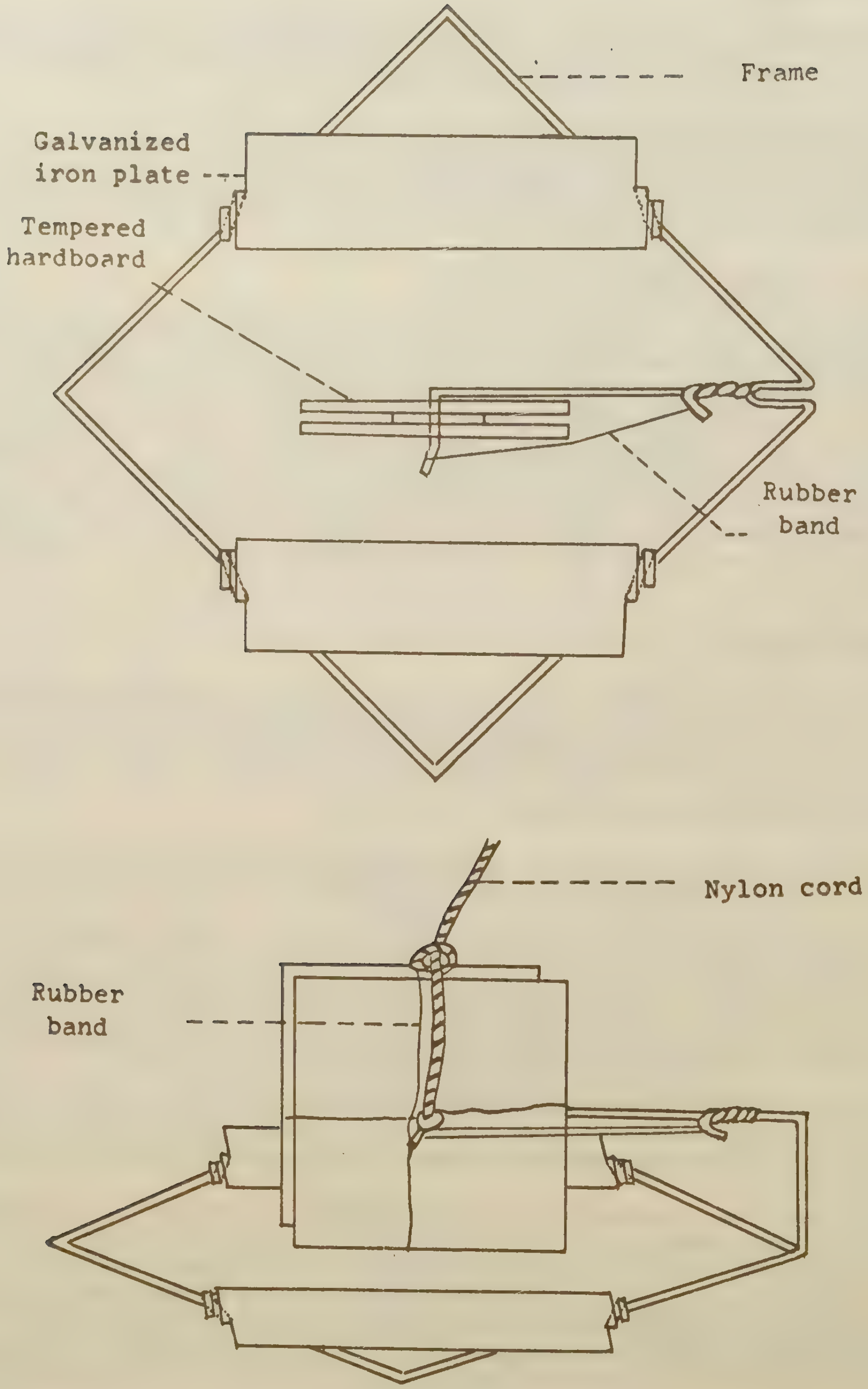
Frame
Galvanized iron plate
Tempered hardboard
Rubber band
Nylon cord
Rubber band

Fig. 1 Multiple-plate sampler supported by a frame to allow contact with the bottom

The analyses of samples from this type of sampler were carried out by a numerical method. The large chironomid larvae and other large aquatic insects were separated from other organisms and debris by the technique described by Lyman (1943). The remainder of the sample was then made up to either 20 or 40 ml depending on the abundance of animals present, and stirred with a magnetic stirrer. Three 1-ml sub-samples were taken and the kinds and numbers of animals present were recorded. Total numbers of different groups were then calculated. The identification of the animals was carried out by using the keys in Edmondson (1959), Johannsen (1936; 1937), Ross (1944) and Pennak (1953).

The multiple-plate sampler described by Hester and Dendy (1962) was used in sampling organisms for determining quantities by the dry weight method.

Two of these samplers were hung on a T-shaped iron stake. In each pond one stake with two samplers was set midway between the two ends of the pond and 0.9 m to 1.5 m from the shore, so that the samplers were kept 0.3 m above bottom and 0.3 m below water surface. All samplers were left in the water for three weeks. At the end of this period, each sampler was enclosed in a small plastic bag before removal from the water, to prevent loss of organisms. The samples were taken to the laboratory to be sorted.

The animals, cases, algae, silt, and other materials on the edges and the inner surface were scraped off with a spatula. After concentration with a Foerst electric plankton centrifuge, the samples were preserved in 70 percent alcohol. A few days later, they were concentrated again and the accumulated organisms and debris were transferred into weighed crucibles, and dried at 60°C in an electric oven for 48 hours. The crucibles with the samples were then kept in desiccators for 24 hours. They were then reweighed and net weights were obtained and recorded.

In order to offer mathematical support of the results obtained, analysis of variance was made with a computer. The results and interpretation are given in the following sections.

The author wishes to express his gratitude to Dr. John S. Dendy for directing this investigation and for criticizing the manuscript.

3 RESULTS

3.1 Samplers in contact with pond bottom

The animals sampled with multiple-plate samplers in contact with the bottom were identified. They are listed in Table II.

The average numbers of the four dominant groups, *Chaetogaster*, copepods, other entomostraca, and chironomid larvae, under different fertilizer treatments are given in Table III; the distributions of these groups with depth are given in Table IV; and the variations in their numbers in different months are given in Table V.

The analysis of variance suggested that there were no significant differences ($P < 0.05$) in numbers of invertebrates with the month or depth of sampling in fertilized or unfertilized ponds. The numbers of the invertebrates from 0-8-2 and 8-8-2 ponds were significantly greater ($P < 0.05$) than those from 0-0-0 ponds, but the effects of 0-8-2 fertilizer treatments upon the invertebrates were not significantly different from those of 8-8-2 treatment.

3.2 Hanging samplers

The monthly variation of dry weights of organisms plus debris on samplers from ponds which received different levels of fertilizer treatment are presented in Table VI.

The analysis of variance indicated that the dry weights sampled in February were significantly greater ($P < 0.05$) than those sampled in December and January. However, there

Table III

The average numbers of four dominant groups per square metre of surface of multiple-plate sampler in contact with pond bottoms, Auburn, Alabama, December 1963 to February 1964

Levels of fertilizer treatment (N-P-K)	Average numbers of dominant groups of invertebrate			
	Chaetogaster	Copepoda	Other Entomostraca	Chironomid larvae
0-0-0	871	839	9,671	1,399
0-8-2	1,872	1,829	65,355	1,269
8-8-2	3,980	2,743	51,111	2,431

Table IV

The average numbers of four dominant groups, g/m^2 of surface of multiple-plate sampler in contact with the bottoms at different depths in ponds, Auburn, Alabama, December 1963 to February 1964

Levels of fertilizer treatment (N-P-K)	Average number of animals at different depths		
	Shallow 0.6 m	Middle 1.2 m	Deep 2.4 m
0-0-0	3,980	2,829	2,786
0-8-2	19,784	18,235	14,771
8-8-2	21,538	12,856	11,543

Table V

The average numbers of four dominant groups, g/m^2 of surface of multiple-plate sampler sampling in different months

Groups	Average numbers of animals in different periods of sampling		
	Dec. 1963	Jan. 1964	Feb. 1964
Chaetogaster	1,947	1,829	2,948
Copepoda	2,066	441	2,948
Other Entomostraca	44,301	41,515	40,321
Chironomid larvae	1,033	1,056	2,711

Table VI

The average dry weights, g/m^2, of organisms plus debris on multiple-plate samplers by months, from ponds which had previously received different levels of fertilizer treatment

Levels of fertilizer treatment (N-P-K)	Months of sampling			
	Dec. 1963	Jan. 1964	Feb. 1964	Average
0-0-0	6.81	6.74	7.34	6.96
0-8-2	7.21	6.89	11.57	8.56
8-8-2	8.24	8.40	12.97	9.87

Table VII

The comparison of average dry weights, g/m^2, of organisms plus debris in winter samples with those in previous summer, Auburn, Alabama, August 1963 to February 1964

Levels of fertilizer treatment (N-P-K)	Seasons of sampling	
	Summer 1/	Winter
0-0-0	9.20	6.96
0-8-2	22.37	8.56
8-8-2	16.97	9.87

1/ Data by courtesy of Dr. J. S. Dendy

were no differences in dry weights between those sampled in December and those sampled in January. The dry weights from 0-8-2 and 8-8-2 ponds were significantly greater ($P < 0.05$) than those from 0-0-0 ponds, but the weights from 0-8-2 ponds were not significantly different from those from 8-8-2 ponds.

The comparison of dry weight of organisms plus debris in winter samples with those from the previous summer samples are given in Table VII. The summer data were obtained from Dr. J.S. Dendy's records. Samples for his study were taken with the same type of samplers exposed in ponds from 21 August to 11 September 1963.

By analysis of variance the dry weights from samples in summer were shown to be significantly greater ($P < 0.05$) than those from the samples in winter. The dry weights from samples of 0-8-2 and 8-8-2 ponds were significantly greater than those from samples of 0-0-0 ponds. There were no significant differences between the dry weights from samples of 0-8-2 ponds and those from samples of 8-8-2 ponds.

4 DISCUSSION

4.1 Evaluation of the multiple-plate sampler in contact with the bottom in sampling of benthic organisms

The results proved that the multiple-plate sampler in contact with the bottom is an effective device for sampling benthos. The samples obtained (i) included seven phyla including at least 31 genera of benthic fauna (Table II); (ii) were adequate for qualitative and quantitative studies; (iii) gave an estimate of the rate of increase of biomass resulting from different levels of fertilization. The fact that there was little or no damage to organisms sampled by this method helped the qualitative and quantitative studies.

The most important benefit of this method is that it shows the numbers of organisms that the water can produce in the absence of fish predation. The space between two plates provides a shelter for those invertebrates which are attracted by the surface of the plates. This shelter was also a desirable place for growth of periphyton.

However, the effectiveness of the device is limited by the selectivity of the substratum by the organisms. Further study will be needed to determine the most desirable length of time for exposing the samplers in water, so that the rate of increase of biomass per unit time most accurately estimates the productive capacity of the environment during the sampling period.

4.2 Estimate of winter populations

There were four dominant groups of invertebrates present in samples in winter. They were Chaetogaster, Copepoda, and "other Entomostraca" including Cladocera and Ostracoda, and chironomid larvae. The counts of these groups showed that the "other Entomostraca" was numerically the most abundant group (Table III). Regardless of the fertilizer treatments, the average numbers per square metre of surface of plates in three-week exposure were Chaetogaster 2,227, Copepoda 1,786, other Entomostraca 41,945, and chironomid larvae 1,702. In the "other Entomostraca" group, the Cladocera appeared more abundant than the Ostracoda, especially in 0-8-2 and 8-8-2 ponds. There were considerable numbers of Nais and Trichoptera, but very few Mollusca, Ephemeroptera, Zygoptera, and Turbellaria were present in samples.

4.3 The effects of previous fertilizer treatment upon the benthic organisms

The results from both the counting method and dry weight method showed that the rate of increase of benthos on samplers in the 0-8-2 and 8-8-2 fertilized ponds were significantly greater than those in 0-0-0 unfertilized ponds, but no significant difference ($P < 0.05$) was demonstrated between rates of increase in 0-8-2 and in 8-8-2 ponds. Both types of multiple-plate samplers gave quite satisfactory results in sampling benthic organisms. Studies in the same ponds by Rabanal (1960) indicated that higher production of benthic invertebrates resulted when fertilizers were applied. The results of this experiment were in agreement with the findings of Rabanal, and those of Ball (1948; 1949; 1951) in Michigan ponds and lakes.

With the exception of the chironomid larvae, the data in Table III and Table V indicate that the rates of growth of benthos in winter responded to the effects of fertilizer applied in the previous spring and summer.

It was observed in this study that Ostracoda from samplers in fertilized ponds differed from those in unfertilized ponds. There were large numbers of young individuals in fertilized ponds, while only a few large ones in unfertilized ponds. This indicated that a large and expanding population occurred in the fertilized ponds.

4.4 Variation due to depth

The average counts of four groups of dominant benthic invertebrates show a variation due to depth in 0-8-2 and 8-8-2 ponds (Table IV). In 8-8-2 ponds, the average numbers in shallow water were considerably higher than those in deeper waters. However, the depth variation was not great enough to show a significant difference by statistical analysis. The results of the analysis, therefore, did not correspond with the findings of other investigators (Howell, 1942; Curry, 1954; McIntire and Bond, 1962). Since these were relatively shallow ponds, no stratification of water occurred during the period of this study, and therefore a uniform growth of populations at all depths could be expected.

4.5 Comparison of the benthic organisms in winter with those in summer

As mentioned in the Introduction, "standing crop" has been considered a poor index of productivity. It is a measure of the quantities of organisms which are left after predation by fish or other predators. Therefore, the standing crop means little unless the populations of predators are known.

Regarding fish predation, Ball and Hayne (1953) observed that the average level of invertebrate fauna for the year following the removal of fish was 2.6 times the average for the two previous years. Dendy (1956) warned that the use of bottom fauna data for assessing productivity should be applied with caution since interpretation is difficult where different species and numbers of fish affect the result through their predation.

The multiple-plate sampler sampled the organisms that were attracted by the artificial substrata and were being protected from predation by fish.

The rate of increase of biomass per unit area of the surface of sampler for a given length of time could be measured by dividing the total biomass by the length of time of exposure and by the area on which the biomass accumulates. This measurement gives a new approach to evaluating the capacity of an aquatic environment in producing biomass. The results showed that the rate of increase of biomass per unit area of protected surface of sampler was greater in summer than in winter.

5 REFERENCES

Ball, R.C., 1948. Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake. Tech.Bull.Mich.agric.Exp.Sta., (206):59 p.

__________, 1949. Experimental use of fertilizer in the production of fish-food organisms and fish. Tech.Bull.Mich.agric.Exp.Sta., (210):28 p.

__________, 1951. The biological effects of fertilizer on a warm water lake. Tech.Bull.Mich. agric.Exp.Sta., (223):32 p.

Ball, R.C. and D.W. Hayne, 1953. Effects of the removal of the fish population on the fish-food organisms of the lake. Ecology, 33(1):41-8

Curry, N.V.L., 1954. Notes on the ecology of the midge fauna (Diptera: Tendipedidae) of Hunt Creek, Montmorency County, Michigan. Ecology, 35:541-50

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Dendy, J.S., Bottom fauna in ponds with largemouth bass only and with a combination of
1956 largemouth bass plus bluegill. J.Tenn.Acad.Sci., 31(3):198-207

Edmondson, W.T. (Ed.), Ward and Whipple's fresh-water biology. New York, John Wiley and
1959 sons, 1272 p.

Gross, F. et al., Application of fertilizers to an open sea loch. Nature, Lond., 158:
1946 187-9

Hester, F.E. and J.S. Dendy, A multiple-plate sampler for aquatic microinvertebrates.
1962 Trans.Amer.Fish.Soc., 91(4):420-1

Howell, H.H., Bottom organisms in fertilized and unfertilized fish ponds in Alabama.
1942 Trans.Amer.Fish.Soc., 71:165-79

Johannsen, O.A., Aquatic Diptera, Part 3. Chironomidae: Subfamilies Tanypodinae,
1936 Diamesinae, and Orthocladiinae. Tech.Bull.Mich.agric.Exp.Sta., (205):1-84

__________, Aquatic Diptera, Part 4. Chironomidae: Subfamily Chironominae. Mem.
1937 Cornell agric.Exp.Sta., (210):1-56

Lyman, F.E., A pre-impoundment bottom-fauna study of Watts Bar Reservoir area (Tennessee).
1943 Trans.Amer.Fish.Soc., 72:52-62

McIntire, C.D. and C.E. Bond, Effects of artificial fertilization on plankton and benthos
1962 abundance in four experimental ponds. Trans.Amer.Fish.Soc., 91(3):303-12

Neess, J.C., Development and status of pond fertilization in central Europe. Trans.Amer.
1949 Fish.Soc., 76:335-58

Pennak, R.W., Fresh-water invertebrates of the United States. New York, The Ronald Press
1953 Company, 769 p.

Rabanal, H.R., The effect of no fertilization and non-nitrogeneous fertilization upon the
1960 chemistry of water, the plankton, bottom organism and fish production in ponds that had received complete (N-P-K) fertilizer for the preceding 15-year period. Unpublished Master's Thesis, Auburn University, Auburn, Alabama

Ross, H.H., The caddis flies, or Trichoptera of Illinois. Bull.Ill.nat.Hist.Surv., 23:
1944 326 p.

Ryther, J.H., The measurement of primary production. Limnol.Oceanogr., 1(2):71-84
1956

Tang, Y.A. and T.P. Chen, The use of chemical fertilizers in the milkfish ponds of Taiwan.
1957 Fish.Ser.Chin.-Amer.Comm.rur.Reconstr., (3):19 p.

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ESSAI DE FERTILISATION DES ETANGS A LA STATION DE RECHERCHES PISCICOLES DE BOUAKE, COTE D'IVOIRE

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Résumé

En vue d'augmenter la production de plancton dans les étangs de pisciculture du type familial, un essai de fertilisation a été entrepris au cours du premier semestre 1965 à la Station de Bouaké, dans des étangs chaulés au préalable.

L'essai préliminaire de chaulage a abouti à un épandage de 500 kg de CaO par hectare tous les 2 ou 3 mois.

Les engrais utilisés furent le sulfate d'ammoniaque et le superphosphate. Le sulfate d'ammoniaque accroît sérieusement la production des étangs chaulés (40 pour cent) et le superphosphate accentue l'influence favorable du sulfate d'ammoniaque (12 à 13 pour cent).

Par contre, le prix de revient excessif de l'opération de chaulage, dans les conditions où elle a été réalisée, diminue considérablement l'intérêt de l'accroissement de production obtenu.

II/E-2

POND FERTILIZATION EXPERIMENT AT THE BOUAKE PISCICULTURE STATION, IVORY COAST

Abstract

In the first six months of 1965 the Bouaké Station carried out an experiment on fertilizing limed family-type fish ponds with a view to increasing plankton growth.

For the preliminary liming 500 kg of CaO per hectare were applied every two or three months.

Ammonium sulphate and superphosphate were used as fertilizers. Ammonium sulphate substantially increases the production of limed ponds (40 percent) and the superphosphate enhances this effect (12 - 30 percent).

Under the conditions of this experiment, gains in the form of increased production are offset by the high cost of liming.

ENSAYO DE FERTILIZACION DE ESTANQUES EN LA ESTACION DE INVESTIGACIONES PISCICOLAS DE BOUAKE, COSTA DE MARFIL

Extracto

Con objeto de aumentar la producción de plancton en estanques piscícolas de tipo familiar, se ha realizado un ensayo de fertilización durante el primer semestre de 1965, en la estación de Bouaké, en estanques previamente fertilizados con cal. Para el ensayo preliminar de fertilización con cal fué necesario utilizar cada dos o tres meses 500 kgs. de CaO por hectárea.

Los abonos empleados fueron sulfato de amoníaco y superfosfato. El sulfato de amoníaco aumentó bastante la producción de los estanques fertilizados con cal (40%) y el superfosfato acentuó la influencia favorable del sulfato de amoníaco (12 a 30%).

En cambio, el excesivo costo de la operación de fertilización con cal, en las condiciones en que se realizó, disminuyó considerablemente el interés del aumento de la producción obtenida.

1 BUT DE L'ESSAI

Pour obtenir une croissance satisfaisante des espèces microphages dans les élevages intensifs effectués dans des étangs à température élevée, il est admis qu'une distribution de nourriture artificielle est généralement recommandée.

Cette nourriture est utilisée par les poissons :

a) en consommation directe d'une part,
b) par décomposition provoquant une prolifération de plancton d'autre part.

Dans les élevages intensifs, cette nourriture doit être distribuée abondamment et régulièrement.

Ceci impose aux pisciculteurs d'apporter aux poissons une quantité souvent importante de déchets ou de sous produits mais surtout de répéter la même opération de nombreuses fois pendant la durée de l'élevage, ce qui a souvent pour résultat de les décourager.

Or un étang peut être considéré comme un vaste milieu de culture pour algues qui servent de nourriture au zooplancton et aux poissons. Il suffit donc de favoriser au maximum leur développement pour accroître sensiblement la production. C'est le but des essais de fertilisation des étangs que nous avons entrepris début 1965 avec le sulfate d'ammoniaque et le superphosphate de chaux dans des étangs préalablement chaulés.

2 ESSAI PRELIMINAIRE DE CHAULAGE DES ETANGS

Cet essai avait pour but de préciser la quantité et la fréquence des épandages de chaux agricole nécessaires pour maintenir le pH au-dessus de 7 et le S.B.V. entre 1,5 et 2,0 (sans chaulage, les étangs de la station ont un pH voisin de 6,9 et un S.B.V. de 1,1).

Trois étangs de 400 m^2, déjà empoissonnés avec Tilapia nilotica, ont été utilisés de septembre à fin décembre 1964, avec des épandages de 20 à 40 kg de chaux agricole à 50 pour cent de CaO, soit 250 et 500 kg de CaO par hectare.

Des mesures de température, pH, S.B.V. et oxygène dissous ont été effectués régulièrement chaque semaine à la même heure. Aucune mortalité n'a été constatée pendant l'expérimentation dont les résultats sont les suivants :

1°- le pH et le S.B.V. s'élèvent aussitôt après l'épandage,

2°- l' augmentation est plus forte après un épandage de 40 kg (soit 500 kg de CaO par hectare),

3°- l'influence sur le pH et le S.B.V. d'un épandage de 20 kg de chaux ne dépasse guère une quinzaine de jours,

4°- l'influence d'un épandage de 40 kg de chaux sur le pH et le S.B.V. dure environ deux mois,

5°- les chiffres de saturation en oxygène dissous auraient tendance à diminuer dans les étangs traités avec 40 kg de chaux agricole.

Le chaulage idéal semble donc être un épandage uniforme de 500 kg de CaO par hectare tous les 2 ou 3 mois.

3 MISE EN PLACE DE L'ESSAI DE FERTILISATION DES ETANGS

L'essai de fertilisation avec le superphosphate et le sulfate d'ammoniaque dans des étangs préalablement chaulés a été mis en place en janvier 1965.

Etangs D3 et D4 : chaulage + sulfate d'ammoniaque + superphosphate
Etangs D6 et D7 : chaulage + sulfate d'ammoniaque
Etangs D8 et D9 : chaulage sans engrais

Tableau I

Essai de fertilisation des étangs préalablement chaulés sans nourriture artificielle
Résultats obtenus après 4 mois d'élevage

Etangs	Espèces	Charge				Vidange							Rdt kg/ha/a
		Date	Nombre	P.moy. (g)	P.total (kg)	Date	Nombre	P.max. (g)	P.moy. (g)	P.min. (g)	Etr.(1) (kg)	P.total (kg)	
1°- Etangs chaulés avec sulfate d'ammoniaque et superphosphate													
D3	T. nilotica	18/1/65	50	72,0	3,600	17/5/65	45	300	255	200		11,480	
	Heterotis nilotica	"	12	93,8	1,125	"	11	635	432	250		4,750	
											2,040	2,040	
					4,725							18,270	1.015
D4	T. nilotica	18/1/65	50	72,0	3,600	17/5/65	46	310	222	130		10,230	
	Heterotis nilotica	"	12	93,3	1,120	"	12	600	438	290		5,260	
											4,930	4,930	
					4,720							20,420	1.177
2°- Etangs chaulés avec sulfate d'ammoniaque													
D6	T. nilotica	18/1/65	50	72,0	3,600	18/5/65	néant						
	Heterotis nilotica	"	12	95,0	1,140								
					4,740								
D7	T. nilotica	18/1/65	50	72,0	3,610	18/5/65	44	290	221	180		9,740	
	Heterotis nilotica	"	12	92,5	1,110	"	12	670	462	160		5,545	
											1,490	1,490	
					4,720							16,775	904
3°- Etangs chaulés sans engrais													
D8	T. nilotica	18/1/65	50	72,0	3,590	19/5/65	38	245	200	110		7,590	
	Heterotis nilotica	"	12	92,1	1,105	"	12	630	429	250		5,150	
											0,410	0,410	
					4,695							13,150	634
D9	T. nilotica	18/1/65	50	72,0	3,610	19/5/65	36	295	238	160		8,570	
	Heterotis nilotica	"	12	92,9	1,115	"	11	550	342	170		3,760	
											1,250	1,250	
					4,725							13,580	664

(1) Les poissons étrangers pêchés dans les étangs sont des *Tilapia zillii* et *nilotica* qui sont passés à l'état d'alevins au travers des grillages lors du remplissage des étangs. Leur poids individuel à la vidange variait de 20 à 80 g maximum.

La durée d'élevage prévue était de 4 mois.

Les opérations de chaulage ont été effectuées les 14 janvier et 13 mars sur la base de 500 kg de CaO par hectare.

Notons que deux jours après le chaulage du 13 mars, on a constaté une mortalité importante de poissons dans l'étang D6 qui a été le seul de la série à réagir de cette façon.

Il semble donc qu'un tel chaulage constitue l'épandage maximum à réaliser pour ce traitement.

L'empoissonnement a été réalisé dans chaque étang de 400 m^2 le 18 janvier 1965 avec :

50 Tilapia nilotica mâles de 72 g .... = 3,600 kg
et 12 Heterotis niloticus de 50 à 150 g .... = 1,100 kg

Les dépôts d'engrais ont été effectués les 22 janvier, 22 février, 20 mars et 21 avril dans des paniers immergés près de la surface de l'étang.

Etangs D3, D4, D6 et D7

50 kg d'N ammoniacal par hectare, soit 2,500 kg de sulfate d'ammoniaque à 21 pour cent par étang et par mois.

Etangs D3 et D4

60 kg de P_2C_5 par hectare, soit 1,325 kg de superphosphate triple à 45 pour cent par étang et par mois.

Pendant toute la durée de l'expérimentation, l'alimentation en eau des étangs a été réglée de façon à compenser seulement les pertes par infiltration et évaporation.

Aucune nourriture artificielle n'a été distribuée aux poissons.

A la fin de la durée d'élevage prévue (4 mois), les étangs ont été vidés complètement et les résultats de la pêche figurent dans le Tableau I ci-après.

4 RESULTATS OBTENUS

Il apparaît nettement :

1°- que, dans des étangs préalablement chaulés, l'engrais a une influence certaine sur la production de poisson,

2°- que le sulfate d'ammoniaque seul accroît de près de 40 pour cent la production des étangs chaulés,

3°- que le superphosphate accentue l'influence favorable du sulfate d'ammoniaque dans des proportions de 12 à 30 pour cent.

5 BILAN ECONOMIQUE DE L'OPERATION

Des données figurant au Tableau II, il apparaît :

1°- que le bilan est dans l'ensemble déficitaire et ceci sans tenir compte des frais d'exploitation divers autres que l'achat des engrais,

2°- que les dépenses effectuées pour le chaulage des étangs sont excessives par rapport à la fertilisation proprement dite avec les engrais chimiques et qu'il y a lieu de réduire le chaulage au maximum pour rendre l'opération rentable.

Tableau II

Bilan économique de l'opération

Etangs			D3	D4	D6	D7	D8	D9
A - Dépenses de fertilisation (frcs CFA)								
Engrais	Poids (kg)	Prix du kg						
Chaux agricole	80	13,50	1.080	1.080	1.080	1.080	1.080	1.080
Sulfate d'ammoniaque	10	18,50	185	185	185	185	-	-
Superphosphate	5,3	27,00	143	143	-	-	-	-
Dépenses totales			1.408	1.408	1.265	1.265	1.080	1.080
B - Produits de la pêche (frcs CFA)								
Prix du poisson = 100 CFA par kg			1.354	1.570	-	1.205	845	885
C - Bilan financier (frcs CFA)								
Bénéfice				162				
Perte			54		1.265	60	235	195

C'est pourquoi nous nous proposons de poursuivre ces essais de fertilisation début 1966 dans des étangs non chaulés d'une part, dans des étangs chaulés avec un épandage plus faible d'autre part, par comparaison avec des étangs chaulés dans les conditions précédentes.

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APPLICATION OF LIMNOLOGICAL AND PRIMARY PRODUCTIVITY STUDIES IN FISH CULTURE

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APPLICATION OF LIMNOLOGICAL AND PRIMARY PRODUCTION STUDIES IN FISH CULTURE

Abstract

Limnology, primary production, and fish yield in five aquatic biotopes were studied. Odathurai tank, a small 50 ha impoundment with continuous inflow and outflow exhibiting very little diurnal variations in chemical parameters, was poor in plankton and the primary production was the lowest of the five types of waters: 1.75 to 6.83 g $O2/m^2/day$. In K.C. Kulam pond and Chinglepet fort moat, wide diurnal variations in alkalinity and dissolved oxygen were noted but depth variations were little. The pH value varied widely as a result of intense photosynthetic activity in Chinglepet fort moat. Vellore fort moat was very similar to these two waters and in addition variations related to depth were also noted in dissolved oxygen, alkalinity and pH, indicating very strong, tropholytic activity in the bottom. The temple pond 'Ayyankulam' resembled Vellore fort moat in marked diurnal and depth variations in dissolved oxygen, alkalinity and pH. Community respiration was very high in Vellore fort moat and K.C. Kulam pond and least in Odathurai tank. Metabolic activities, as indicated by changes in dissolved oxygen, alkalinity, respiration, etc., were well correlated with gross primary production. These are also correlated with other parameters such as hardness, electrical conductivity, calcium, chlorides, phosphate, silicate and plankton. By using the limnological data and the diurnal and depth variations in chemical parameters, it is possible to predict the relative productivity of aquatic biotopes.

EXEMPLES D'ETUDES DE LIMNOLOGIE ET DE PRODUCTION PRIMAIRE APPLIQUEES A LA PISCICULTURE

Résumé

Des études de limnologie, de production primaire et de production de poisson ont été effectuées dans cinq biotopes aquatiques. Le réservoir d'Odathurai, pièce d'eau de 50 ha caractérisé par une alimentation et un écoulement continuels ainsi qu'une très faible amplitude des variations diurnes des paramètres chimiques, s'est révélé pauvre en plancton: la production primaire était la plus faible de toutes celles enrégistrées dans les cinq types d'eau: 1,75 à 6,83 g $O_2/m^2/jour$. Dans l'étang de K. C. Kulam et dans le fossé du fort de Chinglepat, on a constaté que le degré d'alcalinité et la teneur en oxygène dissous, présentaient d'importantes variations diurnes mais variaient peu avec la profondeur. Dans les eaux de Chinglepat, le pH accusait de fortes variations par suite d'une photosynthèse très active. Le fossé du fort de Vellore présente de fortes analogies avec les deux pièces d'eau précitées et, en outre, on y a noté des variations en profondeur de la teneur en oxygène dissous, de l'alcalinité et du pH, ce qui indique une très forte activité tropholytique sur le fond. L'étang du temple d'Ayyankulam présentait les mêmes caractéristiques que le fossé du fort de Vellore en ce qui concerne l'amplitude marquée des variations diurnes et en profondeur de la teneur en oxygène dissous, de l'alcalinité et du pH. La respiration communautaire était très élevée dans le fossé du fort de Vellore et dans l'étang de K. C. Kulam et le plus faible dans le réservoir d'Odathurai. Les activités métaboliques, mesurées par les modifications de l'oxygène dissous, de l'alcalinité, de la respiration etc., correspondaient bien à la production primaire brute. Ces phénomènes ont également été mis en corrélation avec les autres paramètres tels que la dureté, la conductivité électrique, le calcium, les chlorures, les phosphates, les silicates et le plancton. En partant des données limnologiques et des variations diurnes et en profondeur, il est possible de prévoir la productivité relative des biotopes aquatiques.

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APLICACION EN LA PISCICULTURA DE LOS ESTUDIOS LIMNOLOGICOS Y DE LA PRODUCCION PRIMARIA

Extracto

Se han llevado a cabo estudios limnológicos y de la producción primaria así como del rendimiento de peces en cinco biotopos acuáticos. El estanque de Odathurai, pequeño embalse de 50 hectáreas con constante entrada y salida de agua muestra variaciones diurnas muy pequeñas de los parámetros químicos, escasez de plancton, y su producción primaria fué la menor de los cinco tipos de aguas: 1,75 a 6,83 g O_2/m^2/día. En el estanque de K.C. Kulam y en el foso del fuerte de Chinglepat se observaron amplias variaciones de alcalinidad y del oxígeno disuelto si bien las variaciones de profundidad eran pequeñas. El valor del pH varió ampliamente como resultado de una intensa actividad fotosintética en el foso de Chinglepat. El foso del fuerte de Vellore fué muy semejante a dichas dos aguas y además se observaron, relacionadas con la profundidad, del oxígeno disuelto, de la alcalinidad y del pH, lo que indicaba una actividad trofolítica muy intensa en el fondo. El estanque del templo de Ayyankulam se parecía al foso del fuerte de Vellore en las sensibles variaciones del oxígeno disuelto, la alcalinidad y el pH, tanto diurnas como debidas a la profundidad. Las actividades metabólicas, señaladas por los cambios de oxígeno disuelto, alcalinidad respiración, etc., se correspondieron bien con la producción primaria bruta. Estas están igualmente correlacionadas con otros parámetros tales como la dureza del agua, la conductividad eléctrica, calcio, cloruros, fosfato, silicato y plancton. Utilizando los datos limnológicos y las variaciones diurnas y de profundidad en los parámetros químicos es posible predecir la productividad relativa de los biotopos acuáticos.

1 INTRODUCTION

The paramount need to increase protein supply to the inland population has necessitated the use of all available waters for fish culture. Even waters unsuitable initially could be improved to make them fit for fish culture. Despite the intensification of pond culture, adequate accounts of limnological aspects are not available. As part of a program to correlate the biological cycles in ponds with fish production in India a few ponds in Madras state have been studied intensively and the results are presented here.

2 MATERIALS AND METHODS

Ponds were sampled periodically, the water being collected by a Friedinger sampler. The oxygen method (dark and light bottles) was used to estimate primary production as indicated in previous papers (Sreenivasan, 1964a,b,c). The water samples collected were analysed for dissolved gases, dissolved nutrients, etc. according to standard methods, within a few minutes of collection.

3 MORPHOMETRIC FEATURES OF THE PONDS

(i) Vellore fort moat

The Vellore fort moat is an L-shaped pond surrounded with vertical stone walls and 4.8 ha (12.0 acres) in area. It is supplied with the storm-water drainage of the town along with some sewage. Further, direct faecal pollution also occurs. This pond accumulates a lot of fine ooze because it is not completely drained and the outlet is 4.0 m above the bottom. The average depth is 1.5 m, the maximum depth 4.0 m.

(ii) Ayyankulam

This is a typical temple tank, 1.4 ha, with stone-paved steps all round. This is used only for bathing by people and for washing clothes. It is also filled by storm water after rains. The water is less polluted than Vellore moat. The average depth is 3.0 m and maximum depth 7.0 m.

(iii) Chinglepet fort moat

This 2.4 ha moat is very different from the Vellore moat in being very shallow (average depth 1.0 m, maximum depth 3.0 m) and in not being as highly polluted as the latter. It is fed to a small extent by a large irrigation tank known as 'Kolovai lake.'

(iv) Karpurachettikulam (K.C. Kulam)

This is a deep 0.6 ha pond in Chinglepet town used for bathing cattle, washing clothes, etc. This is filled by storm water. The maximum depth is 6 m and average depth 2 m; the shallow areas are very small.

(v) Odathurai tank

This is a large irrigation tank of about 73 ha (180 acres) extent which shrinks to about 40 ha(100 acres)in summer (mean area: 50 ha, 125 acres). This is fed by a seepage stream of Bhavani canal. The bottom is almost flat with very few steep slopes. The maximum depth is about 6.5 m while the average depth is about 1.5 m. There is continuous inflow and outflow for about eight months a year since the water is taken out for irrigation of crops. Thus, this is in fact a small impoundment and plankton blooms are not evident.

4 PHYSICAL AND CHEMICAL FEATURES

4.1 Temperature

Data on physical and chemical conditions are given in Table I. All the five ponds described here are tropical ponds with temperatures not lower than 25.0° C and reaching 36.2°C. Variations in temperature were not wide and thermal stratification was only rarely noted (only in the deep Ayyankulam).

4.2 Free carbon dioxide and alkalinity

A very characteristic feature of these ponds is the absence of free carbon dioxide in the organically enriched ponds, Vellore fort moat, Chinglepet fort moat, Ayyankulam, and in the reservoir-type pond Odathurai. But Karpurachettikulam was different in that free carbon dioxide was present at times and in high concentrations of 22 mg/l. Very high phenolphathalein alkalinity was noted in Vellore moat (128.0 ppm); in Chinglepet moat it was 80.0 ppm, Ayyankulam 50.0 ppm and in Odathurai tank 61.0 ppm. Methyl orange alkalinity was very high in Karpurachettikulam (285 to 722 ppm) and fairly high in Chinglepet moat (164 to 370 ppm) and Odathurai (180 to 484 ppm) and Ayyankulam (100 to 125 ppm). But though mostly high, at times methyl orange alkalinity was absent in Vellore moat at periods when hydroxide alkalinity ensued ($pH > 9.6$).

4.3 pH value

The pH value was always very high in Vellore moat (8.3 to 9.6) and fairly high in Chinglepet moat (7.5 to 9.25), Ayyankulam (7.3 to 9.1) and Odathurai (8.5 to 8.7). In K.C. Kulam it was low on some occasions (6.9).

4.4 Dissolved oxygen

Oxygen disappears from the bottom in Vellore moat and pronounced depletion occurs in the lower layers of Ayyankulam. Even in the very shallow Chinglepet moat, the oxygen content is low even in surface waters in the early forenoon (2.0 mg/l). Similar condition was observed also in K.C. Kulam. However in the large Odathurai tank, the dissolved oxygen was fairly normal, though not as high as in the other four ponds.

4.5 Chloride

The chloride content is very high in Vellore moat, 118 to 715 ppm. In K.C. Kulam it was 190 to 242 ppm, Ayyankulam 190 to 242 ppm, and only slightly less in Chinglepet moat (76 to 124 ppm). It was low in Odathurai tank, 16.5 to 93.0 ppm.

4.6 Hardness and electrical conductivity

Vellore moat had the highest water hardness, 222 to 656 ppm. Ayyankulam and K.C. Kulam waters also had hardness exceeding 200 ppm. Chinglepet moat has also water of high hardness, 113 to 180 ppm. The electrical conductivity of Vellore moat and Ayyankulam are very high (over 1000 µ.mho) and that of K.C.Kulam equally high, 800 to 1,900 µ.mho. Chinglepet moat (475 to 1,150) and Odathurai tank (400 to 525) had moderately high conductivities.

4.7 Nutrients

Very high phosphate content throughout the year is a feature of Vellore moat (0.16 to 4.0 ppm) and K.C.Kulam (0.24 to 1.2 ppm). Soluble inorganic phosphate was not noticed in Chinglepet moat and Ayyankulam at any time. In Odathurai tank, phosphate was occasionally present in small amounts (0.1 ppm). Silicate was very high in Ayyankulam but moderate in other ponds. Nitrate was not detected in any of these ponds at any time.

4.8 Calcium

This was moderately high, over 30 mg/l as Ca, in all the ponds.

5 PLANKTON

There is variation in the occurrence of plankton groups from pond to pond and also in the same pond seasonally.

(i) Vellore moat

This has a predominantly blue-green bloom, especially of *Microcystis aeruginosa*, often to the exclusion of others. A high population of zooplankters was also noticeable here.

(ii) Chinglepet moat

Here, blue-green algae are important at times but not dominant. They occurred along with members of Chlorophyceae in May 1965. The number of genera noticed at times is larger than in other ponds. In August 1964, diatoms were dominant. In November 1964 no blue-greens were noticed but only green algae. Abundant zooplankters were present when blue-green algae were noted.

(iii) Ayyankulam

This pond was dominated by blue-green algae, the most frequent and numerous ones being *Oscillatoria* and *Microcystis* species.

(iv) K.C.Kulam

In this pond, blue greens, Chlorophyceae and colonial flagellates (green algae) were present. Zooplankters were fairly numerous. This pond had a very rich bottom fauna of gastropods, chironomid larvae, oligochaetes, annelids, etc.

(v) Odathurai tank

This was poor in plankton, being a flowing water for the major part of the year. Zooplankters were insignificant. Phytoplankton consisted mainly of diatoms. Gastropods were abundant and a few chironomids and annelids were also present.

In the deeper ponds, such as Vellore moat and Ayyankulam where shallows were limited, bottom fauna is also limited. Even in the shallow Chinglepet moat the bottom fauna was very insignificant. Details of the plankton are given in Table V.

6 PRIMARY PRODUCTION

Productivity measurements are given in Table III. Photosynthetic oxygen production is very high in Vellore moat but a low level is also noticed sometimes (range 1.9 to 42.3 g $O_2/m^2/day$). Ayyankulam shows a steady high production throughout the year (ranging from 16.01 to 29.34 g $O_2/m^2/day$). Chinglepet moat (10.5 to 18.5) and K.C.Kulam (10.0 to 26.1 g $O_2/m^2/day$) also have high production. Odathurai has the least oxygen production of the five (1.75 to 6.83 g $O_2/m^2/day$), but for an impounded water this is normal. Productivity as inferred from oxygen and carbon dioxide changes is high in Chinglepet moat, Vellore moat, Ayyankulam and to a lesser extent in K.C. Kulam and least in Odathurai tank.

7 DISCUSSION

We have under study here four types of waters: (i) two fort moats, (ii) one temple tank, (iii) one village pond, and (iv) a small irrigation impoundment. The two fort moats differ greatly from one another. Chinglepet moat is very shallow and is filled by fresh water from a large rainfed tank and is not heavily polluted by sewage or sullage, in contrast to the Vellore fort moat which is deep and very heavily polluted. The higher temperature of Chinglepet moat is due to its shallowness. Both waters invariably had phenolphthalein alkalinity (free carbon dioxide being absent), but on occasions hydroxide alkalinity occurs in Vellore moat due to very high photosynthesis and consequent utilization of all bicarbonate. In Vellore moat phenolphthalein alkalinity as high as 128 ppm ($CaCO_3$) occurs, while the maximum in Chinglepet moat is 80.0 ppm (Table II). This was lowest in Odathurai tank. The pH value is influenced by changes in carbon dioxide, CO_3'' and HCO'_3. Both the diurnal and depth variations of pH indicate the high metabolic levels of the waters and high productivity. When photosynthesis is high, the pH increases to a high level by afternoon and, as in the case of Vellore moat, even hydroxide alkalinity is produced. Likewise a vertical gradient in pH also indicates high metabolic activity. Due to a high rate of photosynthesis and the concurrent utilization of free carbon dioxide, HCO_3', etc. from the euphotic zone, the pH increases ($CaCO_3$ being precipitated). While due to lack of penetration of sunlight and the consequent inadequacy or absence of photosynthesis no such utilization of free carbon dioxide or HCO_3' occurs in the bottom waters. Further, due to catabolic activity (mainly bacterial), free carbon dioxide increases in the bottom and by attacking the precipitated CO_3'' increases the HCO_3' also. Thus, in productive waters there is a gradient of free carbon dioxide, CO''_3 and HCO'_3. In highly buffered waters, however, the pH gradient may not be very marked. The very slight variation in the pH of Odathurai water is striking. The changes in alkalinity and pH are very low in Odathurai tank indicating a lower rate of photosynthesis. Thus, maximum increase in dissolved oxygen was only 2.0 mg/1. In the other four waters the changes were very great (Table II). The pH value of K.C. Kulam did not rise above 8.6 but touched a low level of 6.9. Ayyankulam and Chinglepet moat recorded the upper value of 9.1.

All the ponds except Chinglepet moat are very hard waters - invariably over 200 ppm $CaCO_3$ - but the former is only moderately hard, not as high as the other four (113 to 180 ppm). The chloride value was also lower in this moat, in contrast to the others, again an indication of milder pollution. The calcium content was high in all the ponds but here again that of Chinglepet moat was slightly lower than that of the others. Electrical conductivity, an index of total dissolved salts, was highest in Vellore moat, next highest in Ayyankulam and K.C. Kulam. It was almost similar in Chinglepet moat, and in Odathurai tank this was also fairly high.

Dissolved oxygen data also reveal the productivity of the waters. Hutchinson's statement (1957) that a skillful limnologist can probably learn more about the nature of a lake from a series of O_2 determinations than from any other kind of chemical data is quite valid for our work. There is a diurnal increase in dissolved oxygen with very low values before day-break and peak value of supersaturation in the afternoon; a wide fluctuation is characteristic of productive biotopes. Also a vertical steep gradient with supersaturation or high saturation at the surface and complete disappearance, or deficit at the bottom, is a characteristic of such waters. High photosynthesis in the euphotic zone results in supersaturation of oxygen in that zone; this zone is severely restricted to a thin layer less than 3 m because of the blanketing effect (Prowse, 1963) of the overgrowth of plankton, sometimes a permanent bloom. The falling plankton, bottom organisms and bacteria all deplete the poor oxygen resources of the bottom layer. Thus we see the spectacle of oxygen supersaturated at the surface and H_2S predominant on the bottom (just below 5 m) in Vellore moat.

The deficit was less severe in the other ponds. In Odathurai tank, which is shallow and also has continuous inflow and outflow refreshing the water, the oxygen deficit is not severe. In larger and deeper reservoirs like Amaravathy, oxygen depletion in the hypolimnion waters has been noticed (Sreenivasan, 1965).

Community respiration or the oxygen consumption in the dark bottle (B.O.D.), also indicates the comparative productive capacity of waters. It is very high in Vellore moat and Ayyankulam, the two most productive waters; it is slightly less in Chinglepet moat and K.C. Kulam, and least in Odathurai tank. Elsewhere (Sreenivasan, 1964b) it has been shown that in oligotrophic lakes there is practically no community respiration. In large sheets of water subject to strong wind action, for example, Odathurai tank, the oxygen change may not show much variation because, if supersaturated, oxygen may escape into the air, while, if undersaturated, oxygen will diffuse into the water by the agitation caused by winds. But in static bodies of water, oxygen changes during day reflect the productivity changes in phenolphthalein and methyl orange alkalinity in open waters. The maximum rate of oxygen production in the euphotic zone measured by the bottle method also reflects the productivity of the biotope (Sreenivasan, 1964a,c).

Overabundance of plankton alone does not increase productivity. The 'self shading effect' of a blanket of algae (Prowse, 1963) restricts the production to only the top 1 m or so in Vellore moat. Also the quality of plankton determines the efficiency of photosynthesis. Excess production of carbon dioxide in K.C. Kulam shows that it is either receiving excess organic matter or is digesting more organic matter than is synthesized by photosynthesis.

As far as fish yield is concerned, it can be seen from Table IV that the output (average of seven or eight years) from Vellore fort moat, Ayyankulam and K.C. Kulam are almost the same. The yield from Chinglepet fort moat was a little lower, but this is because the pond was too shallow (average depth 1.0 m) and the "lebensraum" was very restricted for fishes. The yield from the large 'tank' (an impoundment) Odathurai was lower, less than 100 kg/ha, but this was indicated by the lower rate of primary production and much lower rates of metabolism of the water and the poor plankton. Though chemical parameters of this tank are similar to those for the other four bodies of water, the wide diurnal fluctuations typical of highly productive waters were lacking.

It is thus possible to determine the fish production potential of biotopes by studying primary production as well as the diurnal and depth variations in certain chemical factors, reflecting the metabolism of these waters.

8 ACKNOWLEDGEMENT

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9 REFERENCES

Hepher, B., 1962 Primary production in fish ponds and its application to fertilization experiments. Limnol.Oceanogr., 7:131-6

Huet, M., 1957 Dix années de pisciculture au Congo belge et au Ruanda-Urandi. Trav.Sta.Rich. Groenendaal (D), (22):159 p.

Hutchinson, C.E., 1957 A treatise on limnology. Vol.1. London, John Wiley, 1009 p.

McConnell, W.J., 1963 Primary productivity and fish harvest in a small desert impoundment. Trans.Amer.Fish.Soc., 92:1-12

Prowse, G.A., Neglected aspects of fish culture. *Curr.Aff.Bull.Indo-Pacif.Fish.Coun.*,
1963 (36):1-9

Sarig, S., Fisheries and fish culture in Israel in 1960. *Bamidgeh*, 13(3/4):61-76
1961

Schäperclaus, W., Versuche Zur Ertragssteigerung von Karpfenteichen durch Erhöhung der
1961 Besatzstärke und der Fütterungen in Jahre 1960. *Dtsch.Fisch.-Ztg*, 8(3):79-85

Soong Min Kong, The fitness of ecological niches into which fishes are introduced at
1951 various ages and survival of transplanted fish. IPFC/CSI/Tech.43

Sreenivasan, A., Limnological features of and primary production in a polluted moat at
1964a Vellore, Madras State. *Environm.Health*, 6:237-45

__________, Limnological studies and fish yield in three upland lakes of Madras State,
1964b India. *Limnol.Oceanogr.*, 9(4):564-75

__________, The limnology, primary production and fish production in a tropical pond.
1964c *Limnol.Oceanogr.*, 9(3):391-6

__________, Limnology of tropical impoundments. 3. Limnology and productivity of
1965 Amaravathy Reservoir (Madras State), India. *Hydrobiologia*, 26(3/4):501-16

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Table I

Physical and chemical conditions of the five biotopes

	Temperature °C	Free carbon dioxide ppm	Alkalinity (ppm) $CaCO_3$ Phenolphthalein	Alkalinity (ppm) $CaCO_3$ methyl orange	pH	Dissolved oxygen mg/l	Chloride
Vellore fort moat	26.0-31.8	0.0	2.0-128.0	0.0-64.0	8.3-9.6	0.0-27.3	118-715
Chinglepet fort moat	26.8-33.0	0.0	1.0-80.0	164-370	7.5-9.25	2.0-16.6	76-124
Ayyankulam	25.0-34.2	0.0-0.0	7.5-50.0	100-225	7.3-9.1	0.6-19.2	93-280
K.C.Kulam	28.8-36.2	0.0-22.0	0.0-66.0	285-722	6.9-8.8	1.2-16.6	190-242
Odathurai tank	27.2-33.5	0.0	23.7-61.0	180-480	8.1-8.7	5.0-9.6	16.5-9.30

	Hardness $CaCO_3$ ppm	Electrical conductivity µ.mho	Phosphate mg/l	Silicate mg/l	Calcium mg/l	Oxygen absorbed
Vellore fort moat	222-656	975-2805	0.16-4.0	2.5-60.0	44.8-56.3	5.4-17.1
Chinglepet fort moat	113-180	475-1150	Nil-Tr	1.2-3.5	15.5-37.8	0.8-4.4
Ayyankulam	264-314	1075-1370	0.0	50-66.0	43.6-52.1	4.7-17.0
K.C.Kulam	170-245	800-1900	0.24-1.2	1.2-6.4	33.0-64.4	4.7-8.6
Odathurai tank	126-284	400-525	0.10-0.0	2.2-4.2	41.6-26.0	8.2

Table II

Variations in certain chemical conditions

A. Diurnal variations (surface)

		Free carbon dioxide ppm	Alkalinity (ppm) $CaCO_3$		Dissolved oxygen mg/l	pH
			Phenolphthalein alkalinity	Methyl orange alkalinity		
Chinglepet fort moat	(a)	..	32.0-88.0	158-59	2.4-17.6	8.0-9.25
	(b)	..	44.0-70.0	360-293	3.6-10.8	8.1-8.6
K.C.Kulam	(a)	14-12	27.8-68.5	444-187	3.2-15.6	8.2-8.8
	(b)	..	0.0-19.0	390-385	5.6-9.8	7.9-8.0
Vellore fort moat	(a)	..	50.0-128.0	280-198	13.6-27.0	8.2-8.8
	(b)	..	67.5-67.5	225-225	8.2-10.8	8.9-9.0
Ayyankulam	(a)	..	30.0-50.0	165-118	5.4-18.4	7.9-8.8
	(b)	..	17.0-22.0	150-142	5.6-13.4	8.6-8.9
Odathurai tank	(a)	..	61.0-72.0	205-178	8.2-10.6	8.5-8.6
	(b)	..	45.0-45.0	411-402	5.0-5.7	8.7-8.7

B. Depth variations

		Free carbon dioxide ppm	Alkalinity (ppm) $CaCO_3$		Dissolved oxygen mg/l	pH
			Phenolphthalein alkalinity	Methyl orange alkalinity		
Chinglepet fort moat	(a)	0.0-6.2	30.0-4.4	360-370	2.6-1.8	7.8-7.5
	(b)	..	4.0-4.0	302-304	2.0-2.0	7.9-7.9
K.C.Kulam	(a)	14.0-22.0	24.0-28.0	444-468	3.2-1.2	7.1-6.9
	(b)	..	12.0-12.0	390-390	2.6-1.2	8.2-8.2
Vellore fort moat	(a)	0.0-45.0	27.5-67.5	225-366	13.6-4.8	9.2-8.7
	(b)	..	32.5-35.0	280-290	3.4-3.2	8.9-8.8
Ayyankulam	(a)	0.0-5.0	0.0-17.0	150-225	19.0-1.4	8.9-8.8
	(b)	..	10.0-15.0	165-170	5.4-4.6	7.9-7.6
Odathurai tank	(a)	..	23.0-33.0	205-224	7.4-6.4	8.1-7.9
	(b)	..	..	..	..	..

(a) Greatest change in a day

(b) Least change in a day

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Table III

Productivity measurements of the five biotopes

	Primary production		Productivity rates µ mol/l/hr			Secchi disc visibility cm	Community respiration mg/l/h/O_2
	Gross g O_2/m^2/ day	Maximum rate mg/m3/ day	By oxygen change method	By changes in alkalinity	From maximum rates in bottle experiment		
Vellore fort moat	1.9-42.3	6.67-45.15	11.0-125.0	8.0-250.0	3.50-123.0	21-80	0.13-0.92
Chinglepet fort moat	10.5-18.5	30.0-34.4	30.0-55.0	78-176	78.1-90.0	31-50	0.17-0.45
Ayyankulam	16.0-29.3	19.73-37.07	37.0-100.0	16-183	52.0-96.0	30-60	0.15-1.30
K.C.Kulam	10.0-26.06	14.4-57.6	22.0-50.0	12.0-230.0	38.0-150.0	35-68	0.20-0.34
Odathurai tank	3.15-6.83	2.6-20.7	3.0-7.8	0.0-51.0	2.6-30.0	15.0-71*	0.03-0.2

* Turbidity due to 'Tripton'

Table IV

Fish yield in the five biotopes
(Total in kg - figures in parentheses kg/ha)

Year	Vellore fort moat	Chinglepet fort moat	K.C.Kulam	Ayyankulam	Odathurai tank
1	2	3	4	5	6
1957-58	10,470 (2,169)	No data	217(362)	2,278(1,627)	2,842(57)
1958-59	10,740 (2,239)	659(275)	323(538)	1,121(801)	3,777(72)
1959-60	7,678 (1,600)	2,414(1,007)	719(1,198)	2,204(1,574)	3,485(70)
1960-61	6,288 (1,310)	2,153(900)	771(1,285)	3,687(2,633)	6,363(127)
1961-62	4,178 (870)	2,311(963)	1,017(1,695)	1,733(1,245)	4,465(89)
1962-63	4,926 (1,027)	2,506(1,044)	1,205(2,008)	1,901(1,358)	5,231(105)
1963-64	2,260 (471)	2,912(1,240)	1,469(2,448)	2,013(1,438)	5,388(108)
1964-65	No data	3,270(1,363)	1,849(3,081)	No data	3,008(60)

Table V

Plankton of the five biotopes

Vellore fort moat	Ayyankulam	Chinglepet fort moat	K.C.Kulam	Odathurai tank
5-200 µl/l	5-30 µl/l	100-30 µl/l	100-300 µl/l	1 µl/l
Microcystis (permanent bloom)	Oscillatoria	Spirulina	Miscrocystis	Oscillatoria
	Microcystis	Nostoc	Nodularis	Microcystis
Anabaena	Merismopedia	Oscillatoria	Nostoc	Navicula
Nostoc	Lyngbya	Microcoleus	Merismopedia	Cyclotella
Scenedesmus	Scenedesmus	Tetrapedia	Tetrapedia	Gyrosigma
Ankistrodesmus	Peridinium	Merismopedia	Oscillatoria	Ankistrodesmus
Ulothrix	Euglena	Microcystis	Selenastrum	Fragilaria
Aphanizomenon	Rhaphidiopsis	Maugeotia	Scenedesmus	Pediastrum
Ulothrix	Navicula	Stephanodiscus	Crucigenia	Spirulina
Navicula	Nitzschia	Navicula	Pediastrum	Spirogyra
Cyclotella	Ankistrodesmus	Nitzschia	Tetraspora	Tetrapedia
Noduloria	Volvox	Cyclotella	Ophiocytium	Euglena
Phormidium	Ulothrix	Amphora	Euglena	Ceratium
Selenstrum		Melosira	Volvox	Navicula
		Scenedesmus	Pandorina	Scenedesmus
		Cocconeis	Closterium	Microcoleus
		Staurastrum	Chlorella	
		Selenastrum	Cosmarium	
		Peridinium	Navicula	
		Oocystis	Phacus	
		Closterium	Oocystis	
		Tribonema	Staurastrum	
		Pediastrum	Amphora	
		Pandorina		
		Eudorina		
		Pleodorina		
		Pinnularia		
		Diatoma		
		Synedra		
		Cosmarium		
		Ceratium		
		Euglena		
		Nodularia		

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PROBLEMS IN CARP POND FERTILIZATION

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Abstract

Fertilization experiments were run on the carp ponds of a total area of more than 300 ha, for four years. Different doses of calcium and different doses and frequencies of phosphorus or phosphorus plus nitrogen fertilizers did not increase yield in the majority of cases. Experiments indicated that even a negative influence of fertilization on yield could exist. When the results of experiments were applied on a country-wide scale, the use of fertilizers on fish farms was lowered by about 48 percent without any negative effect on yield and feed coefficient. Chemical analyses of inflow water and water in ponds showed high concentrations of phosphorus and nitrogen and a sufficient concentration of calcium. As inflow water influenced positively the balance of elements in ponds, fertilization under such conditions seemed to be unnecessary. Supplementary feeding with cereal's in densely stocked ponds is considered to be another factor which enriched the ponds with phosphorus and nitrogen. It was presumed that the analyses of factors influencing the balance of nutritive elements in ponds would give an indication whether fertilizers should be used or not.

PROBLEMES DE FERTILISATION DES ETANGS DE CARPICULTURE

Résumé

Des expériences de fertilisation ont été menées pendant quatre ans dans des étangs à carpe couvrant une superficie totale de plus de 300 hectares. Différentes doses de calcium et différentes doses de phosphore ou d'engrais phosphorés et azotés déversées à des intervalles variables n'ont entraîné, dans la plupart des cas, aucune augmentation de la production. Il semblerait même que la fertilisation puisse avoir une influence négative sur le rendement. A la suite de ces expériences, l'utilisation d'engrais dans les établissements piscicoles de l'ensemble du pays a été diminuée d'environ 48% sans que l'on constate d'effets négatifs sur la production et sur le coefficient de conversion alimentaire. L'analyse chimique des eaux d'alimentation et de l'eau des étangs a révélé de fortes teneurs en phosphore et en azote et une concentration suffisante de calcium. Etant donné l'enrichissement des étangs dû aux eaux d'alimentation, il est apparu que la fertilisation était inutile dans ces conditions. L'auteur estime que le déversement d'aliments d'appoint à base de céréales dans des étangs fortement peuplés contribue également à élever la teneur des eaux en phosphore et azote. L'analyse des facteurs influant sur l'équilibre des éléments nutritifs des étangs devrait vraisemblablement donner une indication quant à la nécessité d'employer des engrais.

PROBLEMAS DE LA FERTILIZACION DE LOS ESTANQUES DE CARPAS

Extracto

Se llevaron a cabo experimentos de fertilización en los estanques dedicados a la cría de la carpa con una extensión total de más de 300 ha durante cuatro años. Diferentes dosis de calcio y diferentes dosis y frecuencias de aplicación de fertilizantes fosforados, o fosforados y nitrogenados, no hicieron aumentar el rendimiento en la mayoría de los casos. Los experimentos indicaron que incluso podría existir una influencia negativa de la fertilización sobre el rendimiento. Cuando se aplicaron los resultados de los experimentos al plano nacional, el empleo de fertilizantes en las granjas piscícolas disminuyó en casi el 48 por ciento sin ningún efecto negativo en el coeficiente de rendimiento y de alimentación. Los análisis químicos de las aguas afluentes y de las aguas de los estanques mostraron altas concentraciones de fósforo y de nitrógeno y una concentración suficiente de calcio. Como las aguas afluentes hicieron variar positivamente el equilibrio de los elementos en los estanques, la fertilización en tales condiciones pareció ser innecesaria. La alimentación suplementaria con cereales en estanques densamente poblados se considera otro factor que hizo aumentar el fósforo y el nitrógeno en los estanques. Se supone que el análisis de los factores que influyen en el equilibrio de los elementos nutrientes en los estanques podría dar una indicación acerca de si se deben utilizar fertilizantes o no.

1 FERTILIZATION EXPERIMENTS

1.1 Moderate and heavy fertilization with nitrogen, phosphorus and calcium

Bojčić *et al*. (1960; 1961) showed that higher stocking density, intensive feeding and fertilization resulted in the significant increase of carp (*Cyprinus carpio*) yield in fattening ponds in Yugoslavia. The higher rates of stocking and intensive feeding were adopted in fish farms all over the country and a considerable increase of the average yield was thus obtained.

The question arose whether it is possible to get even higher yields by improving the methods of fertilization. As experimental ponds were not available, experiments were conducted under field conditions in fattening ponds on three fish farms from 1961 to 1963. The results of experiments in 11 ponds on three fish farms were summarized by Fijan *et al*. (1964) after three years. Surprisingly, different doses of phosphorus (37.5 to 135.8 kg/ha P_2O_5), phosphorus + nitrogen in doses and frequencies as on fish farms in Israel (Livojević, 1961), and different doses of calcium had not increased the yields. Three of four unfertilized ponds gave higher yields than fertilized ponds stocked at the same rate. In one unfertilized pond the yield was 10.7 percent lower than that of the fertilized pond of the same group.

Two ponds (one in the Našice fish farm and the other in the Končanica fish farm) were not fertilized for two years. This did not decrease the yields compared with average yields during three previous years or yields in fertilized ponds of the same group. (Tables I and II). On the contrary, the unfertilized pond in Končanica gave the best yield compared with 22 other ponds on the farm which had been all fertilized with phosphorus or calcium + phosphorus.

Table I

Yields in an unfertilized pond (Group I) and four fertilized ponds (Group II) in Končanica

Year	Group	Yield kg/ha	Differences in yield (fertilized = 100%)	Feed coefficient
1959-1961	I*	1,090	99.1	
	II	1,100	100.0	
1962	I	1,636	116.9	2.65
	II	1,400	100.0	2.52
1963	I	1,805	117.2	2.83
	II	1,540	100.0	3.40

* the pond was fertilized before the experiment

Table II

Yields in unfertilized ponds (Group I) and fertilized ponds (Group II) in Našice

Year	Group	Yield kg/ha	Differences in yield (fertilized = 100%)	Feed coefficient
1959-1961	I*	894	99.3	
	II	900	100.0	
1962	I	1,051	100.2	2.8
	II	1,049	100.0	3.0
1963	I	1,150	105.4	2.46
	II	1,093	100.0	2.24

* the ponds were fertilized before experiment

Organic fertilizers - pig manure and grass - were used in experiments during 1961. It was concluded that they did not have a clear influence on the yield. On the other hand, pig manure was not available in sufficient quantities to be widely applied and the costs for manual labour in zonal green fertilization with grass (method described by Martÿsev, 1958), were too high.

Routine analyses of plankton and bottom fauna did not show differences between the ponds in the experiment. Chemical analyses of the water also did not show any differences (Asaj et al., 1962; Asaj and Fijan, 1966).

1.2 Experiments with phosphorus only

Influenced by the fact that the majority of workers considered phosphorus fertilization of greatest importance, and by Hickling's (1962) statement, that "it is unlikely that a case exists where phosphates would not be beneficial", we continued the experiments with superphosphate only in 1964. It was planned to experiment on the same three fish farms as during 1961-63, but unfortunately the rates of stocking were not the same among the groups of ponds on two fish farms. The results obtained did not, therefore, allow us to draw any definite conclusion, but we gained the impression that in Poljana the yield was higher in the fertilized pond and in Našice the yield was higher in the unfertilized pond. So we took into consideration only the results in Končanica where the experiments were set up under comparable conditions.

The ponds in Končanica are more than fifty years old and on an average about 1.5 m deep. The bottom is non-porous and covered with mud of neutral or slightly alkaline reaction. Twelve ponds varying in size from 9 to 48 ha (total area 282 ha) were divided into three groups of two ponds and two groups of three ponds. As is shown in Table III, during the preceding four years the ponds in each group had similar stocking rates and yields. In group V the ponds were partially covered by emergent vegetation and all other ponds were free of it. All of the ponds had been fertilized with lime and superphosphate for many years.

In spring 1964 the rates of stocking were not the same in all groups because of the differences in fertility among the groups and because of the demand for fish of different sizes. The groups differed also in average weight of carp fry and rate of

Table III

Fertilization experiments on Končanica Fish Farm in 1964

Group	Pond number	Average values before experiment			1 9 6 4					
		Stocking carp/ha	Net yield kg/ha	Feed coef.	Stocking carp/ha	Super-phosphate kg/ha	Fished out carp/ha	Net yield kg/ha carp	Net yield kg/ha total	Feed coef.
I.	19	1,500	1,483	3.14	1,500	-	1,485	1,826	1,863	2.43
	21	1,275	1,417	2.02	1,500	6 x 70	1,353	1,481	1,569	2.87
II.	10	1,160	1,760	2.15	1,500	-	1,381	1,505	1,557	2.71
	29	1,370	1,428	2.37	1,500	-	1,350	1,232	1,407	2.89
	8	1,362	1,408	1.95	1,500	300	1,101	1,172	1,209	3.42
III.	11	930	1,233	1.71	1,300	-	1,242	1,662	1,720	2.17
	14	1,025	1,446	2.11	1,300	300	1,147	1,442	1,527	2.64
IV.	23	836	1,143	2.18	1,000	-	989	1,213	1,290	2.32
	14b	850	1,072	2.01	1,000	300	895	891	1,007	2.78
	22	987	1,211	1.71	1,000	300	891	1,262	1,357	1.85
V.	2	725	860	2.25	1,000	-	946	833	901	3.47
	1	725	831	2.25	1,000	300	986	955	1,048	2.85

stocking of additional fish (tench, pike perch, catfish). But within the groups the average weight of carp fry and amount of additional fish stocked were the same (see Table III).

In group I superphosphate was added in nine doses at fortnightly intervals. In other groups the fertilizer was added in one dose at the end of May. Lime or other calcium fertilizers were not used at all.

Fish were fed with maize and lower quality wheat and the daily amount of feed was regulated according to the feeding practice on the fish farms in Yugoslavia. The total amount of feed given per ha did not differ significantly in the ponds within the same group. The emptying of the ponds took place late in autumn when there was no growth of carp.

In the first three experimental groups the net yield of carp, the total net yield and the feed coefficient were better in the unfertilized ponds. The average values for two fertilized in group IV were somewhat lower than the values in the unfertilized pond. In group V better results were achieved in the fertilized pond.

Considerable differences in real density, i.e. number of carp fished out per ha, were found in the ponds of the same group. This is not unusual and could sometimes happen in the experimental ponds as well. In our opinion such marked differences as in some groups of our experiment could not be corrected adequately, but to prove the impression that the yields were better in unfertilized ponds a rough correction was made. In each group the number of carp fished out was equalized in all ponds to the density found in the pond with the lowest losses. The mean weight of carp fished out was calculated for every pond, and based on this the gain in weight was estimated. As it is known that carp grown under the same conditions but at higher densities will have lower mean weight, and as the fertilized ponds had higher losses than unfertilized ones, this correction of net yields was more favourable for the fertilized ponds. Table IV shows that even after this rough correction of yields there was no visible positive influence of phosphorus fertilization in our experiment.

Table IV

Differences in net yield and corrected net yield between fertilized and unfertilized ponds (fertilized = 100%) in Končanica in 1964

Experimental group	Net yield in unfertilized ponds (net yield in fertilized ponds = 100%)		
	before experiment	in experiment	after correction
I	104.6	116.4	106.6
II	113.2	112.6	99.3
III	85.3	112.6	104.5
IV	100.0	109.1	99.4
V	103.5	86.0	89.3
Average I-V	105.6	113.2	103.4

1.3 Application of the results of experiments

As the experiments were conducted on fish farms the results achieved were immediately applied. The yearly reports on the experiments also contributed to the diminished use of fertilizers on the fish farms.

According to Basioli (1965) the use of fertilizers per unit area of fish ponds in Croatia in 1964 was 46 percent lower than in 1961. The yield and the use of supplementary food remained at the same level. The statistical data for fish farms in Yugoslavia showed that the use of fertilizers for production of one kg of fish decreased from 1.75 kg in 1961 to 0.71 kg in 1964 (Pažur, personal communication). The average yield and the food conversion did not change significantly.

The analysis of the data given by Basioli (1962; 1965) on the use of different fertilizers showed that the average dose of phosphorus fertilizers decreased from 346 kg/ha in 1961 to about 247 kg/ha in 1964. Nitrogen fertilizers (112 kg/ha in 1961) were not in use any more. The use of the calcium fertilizers decreased from 1,105 kg/ha in 1961 to 596 kg/ha in 1964. It has to be noted that lime used for disinfection and for treatment during outbreaks of branchiomycosis and summer oxygen deficiency was considered as calcium fertilization. A further drop in use of fertilizers is expected in 1965.

2 FACTORS COUNTERACTING THE POSITIVE EFFECTS OF FERTILIZATION

2.1 Water

The quality of water supply of the ponds could have an influence on the effect of fertilization. A good example of this was given by Hepher (1962). In the experimental station Sdeh-Nahum in Israel fertilization increased the yields by 74 percent and at the experimental station Dor sometimes even by 732 percent. These differences were attributed to the differences in inflow water quality. Wróbel (1963) found that the need for fertilization with calcium depended on the amount of this element in the water supply. When there was 40 mg/l or more calcium in the inflow water, there was no need for liming. Müller (1958) stated that the yields were not increased when lime was added to ponds sufficiently rich in calcium. The ponds in our experiments were supplied water rich in phosphorus, calcium and nitrogen (Asaj and Fijan, 1962; 1966). The concentration of phosphorus in inflow water of Končanica, Poljana and Našice varied between 1.4 and 4 mg/l. This means that the experimental ponds received from the inflow water yearly an amount of phosphorus that is equal to the doses of about 225 to 642 kg/ha of superphosphate. This could explain the inability of phosphorus fertilizers to increase the yields.

The inflow water on all three farms contained more than 40 mg/l of calcium. Our experiments showed in accordance with data given by Müller (1958) and Wróbel (1963), that there was no need for liming under such conditions. Hepher (1958) found that excess lime precipitated phosphates, and Hickling (1962) that excess limestone slightly decreased the fish crop in ponds fertilized with phosphate.

Water could influence the balance of elements in ponds. According to Wróbel, a water supply rich in calcium could increase the calcium deposited on the bottom. On the other hand water poor in calcium would take it from the bottom.

When we compared data on the concentration of calcium in the inflow water and in the waters of our experimental ponds before emptying, we found a decrease of about 10 to 15 mg/l. This calcium remained in the pond mud or was used by fish directly or indirectly. About 50 to 70 percent of phosphorus, and an even higher percentage of nitrogen compounds entering with the water also remained in the pond. This indicated that the inflowing water acted as a fertilizing agent bringing nutrients into the ponds. Although literature indicates that many waters are not so rich in mineral nutrients as our waters, the fertilizing effect of the inflow water, and its effect in the pond should always be taken into account.

The fact that in all experimental ponds the phosphorus level in the water was rather high could be explained by the assumption of Hepher (1958) that in older fish ponds the adsorption of phosphate by the mud will decrease as the result of the accumulation of organic matter on the bottom, and partial saturation of the adsorption complex by regular fertilization with phosphate. Hickling (1962) supposed also that in long-established ponds which had developed mud rich in organic matter, the fixation of phosphate would be lower. In view of this, we are of the view that phosphorus and organic fertilization is unnecessary in old ponds like the ones used in our experiments.

2.2 Stocking rate and supplementary feeding

The main characteristics of intensive fish culture are high stocking rates and supplementary feeding. When the higher stocking rates and intensive feeding were adopted in carp fish farms in Yugoslavia the average yield increased. These measures could also influence the effect of fish pond fertilization. The general belief exists that the benefits of fertilization will be even greater when the carp are intensively fed.

Although the fertilization effect of supplementary feeding is generally recognized, only Gieraltowski (1961) calculated the amount of faeces and urine excreted by carp in an intensively managed pond. He found that a crop of 1,000 kg/ha of carp would produce about 11,000 kg/ha of excreta during the growing season in Poland. According to data published by the National Academy of Sciences, U.S.A. (Anon, 1958) maize contains 85-88.5 percent of dry matter. Our preliminary investigations showed that carp from our fish ponds contained about 31 percent of dry matter. From these data we calculated that about 2,350 kg/ha of organic matter or its components and salts would remain yearly in a pond with a yield of 1,500 kg/ha and feed coefficient of 2.2.

The influence of feeding on the balance of elements is of even greater importance. Schäperclaus (1961) calculated that about 10 kg/ha P_2O_5 would be taken out from a pond with a yield of 500 kg/ha. But about 8 kg/ha P_2O_5 was brought into the pond by the feeding with barley. Schäperclaus used for this calculation data from Geng _et al_. who found that the maximum P_2O_5 content of living carp could be 2 percent. Our analysis showed the phosphorus content of a carp from the fertilized pond to be about 0.4 percent, i.e. about 0.92 percent of P_2O_5. Our carp is the mirror carp variety with only few scales and, as it is fleshy and fat, its skeleton forms a smaller part of the body than of some other varieties of carp. This could explain the relatively low content of phosphorus in our carp. As maize contains about 0.3 percent and carp about 0.4 percent of phosphorus, we assume that about 3.9 kg of phosphorus, i.e. 8.9 kg/ha P_2O_5 will remain yearly in a pond with the yield of 1,500 kg/ha and feed coefficient of 2.2. This calculation shows that under conditions of our experiments positive influence of feeding on phosphorus balance in ponds existed. The higher the yield and the feed coefficient, the more positive is the balance of phosphorus in the pond. Generally speaking, the balance of phosphorus in the pond can be influenced by (a) the stocking rate, which is the determinant factor for the size of yield and feed coefficient, (b) the kind and amount of the supplementary food, as well as (c) species of fish, their size and condition.

Such positive or negative influence of the above-mentioned factors must also be expected for the balance of other elements in the pond. We calculated the differences in the balance of nitrogen that could exist in a pond if the yields varied between 500 and 2,500 kg/ha and conversion rates of maize varied from 0.5 to 2.5. For these calculations we used the finding of Livojević (1964) that our carp contained about 14 percent of protein. The content of maize was taken as 9.3 percent for these calculations (i.e. the mean value of two sets of data mentioned in Anon., 1958). At the yield of 500 kg/ha and a feed conversion of one, the balance would be negative for 3.76 kg/ha. The same feed conversion at the yield of 1,000 kg/ha would make the balance negative for 7.52 kg/ha. At the yields of 2,000 and 2,500 kg/ha and at the feed coefficient of 2 or 2.5 the balance would be positive for 14.7 or 29.6 kg and positive for 18.4 or 37.3 kg/ha of nitrogen. In intensive carp culture feeding with maize will benefit the nitrogen balance in pond. Of course other feeds, other compositions of fish, or species of fish raised, could influence the nitrogen balance differently. The inflow water and nitrogen exchange with air also would influence this balance.

Higher yields and higher individual weights of fish in the majority of unfertilized ponds in our experiments indicated the possibility of a negative influence of fertilization with superphosphate. Such an indication is very exceptional and could only be compared to findings of Wróbel (1965), who stated that polytrophic levels in the pond caused by intensive feeding, could deteriorate the oxygen conditions sufficiently to provoke heavy mortalities. In our experiments, in 1964 we noted a higher mortality in fertilized ponds, but we did not find any marked differences in oxygen content from periodical routine analyses, or the symptons of oxygen deficiency or mass mortality. However, influence on the oxygen conditions seems to be the only explanation for the higher losses and presumed negative effect of fertilization on yields.

3 CONCLUSIONS

The fertilization of long-established and well cultivated carp ponds seems to be unnecessary when they are supplied with water rich in calcium, phosphorus and nitrogen, and the fish are intensively fed with cereals. Under such conditions fertilization could even depress the yield.

The amount and the chemical composition of inflow water, supplementary feeds and fish crop could all have different influences on the balance of nutritive elements in the pond. The analyses of these factors could give an indication whether a pond requires fertilization.

4 REFERENCES

Asaj, A. et N. Fijan, Zapažanja pri umjetnom gnojenju ribnjaka. Vet.Arh., 36(1-2):41-8
1966

Asaj, A. *et al.*, Neki podaci o količini dušika, fosfora i kalcija u vodi različito
1962 gnojenih ribnjaka. Vet.Arh., 32(3-4):83-91

Basioli, J., Slatkovodno ribarstvo NR Hrvatske u 1961 godini. Ribarst.Jugosl., 17(2):
1962 46-52

____________, Slatkovodno ribarstvo SR Hrvatske u 1964 godini. Ribarst.Jugosl., 20(3):
1965 59-63

Bojčić, C. *et al.*, Pokusu u svrhu povećanja prinosa u šaranskim ribnjacima pomoću gustog
1960 nasada na ribnjačarstvu Poljana 1959 godine. Ribarst.Jugosl., 15(1):1-7

Bojčić, C. et al., Proizvodni pokusi za povećanje prinosa na šaranskim ribnjacima u
1961 1960 godini. Ribarst.Jugosl., 16(1):3-7

Fijan, N. et al., Rezultati trogodišnjih pokusa o gnojenju šaranskih ribnjaka u
1964 praktičnim uslovima. Ribarst.Jugosl., 19(5-6):123-39

Gieraltowski, M., W sprawie nawozenia stawów. Gospod.rybna, 13(5):28-32
1961

Hepher, B., On the dynamics of phosphorus added to fish ponds in Israel. Limnol.
1958 Oceanogr., 3(1):84-100

___________, Ten years of research in fish ponds fertilization in Israel. 1. The
1962 effect of fertilization on fish yields. Bamidgeh, 14(2):29-38

Hickling, C.F., Fish Culture. London, Faber and Faber, 295 p.
1962

Livojević, Z., Slatkovodno ribarstvo Izraela. Ribarst.Jugosl., 16(6):146-54
1961

___________, Nove metode uzgoja šarana i postizanje visokih prinosa u ribnjacima.
1964 Zagreb, Unpubl.Diss. 171 p.

Martyshev, F.G., Prudovoe rybovodstvo. Moskva, Sovetskaia Nauka, 584 p.
1958

Müller, W., Teichdüngungsversuche mit Kalk, Phosphat und ihrer Kombination in
1958 Königswarta (Lausitz). Z.Fisch., 7(7/8):583-9

Schäperclaus, W., Lerbuch der Teichwirtschaft. Berlin, Parey, 582 p.
1961

Wróbel, S., Chemische Untersuchungen von Fischteichen in der Woiwodschaft Kielce.
1963 Acta hydrobiol., Kraków, 5(2-3):215-27

___________, Causes and consequences of pond eutrophication. Acta hydrobiol.,
1965 Kraków, 7(1):27-52

Anon., Nutrient requirements of domestic animals. 4. Nutrient requirements of beef
1958 cattle. Publs.natn.Res.Coun.,Wash., (579):32 p.

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II/E-5

LA FERTILISATION ET SON INFLUENCE SUR L'AUGMENTATION DE LA PRODUCTION PASSAGERE ET FINALE DANS CERTAINS ETANGS DE VOJVODINA

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Résumé

On a étudié quelques uns des étangs de Vojvodina, dans les conditions de pratique (Susek, Jegrička, Futog) et expérimentales (Čurug). On a observé que l'augmentation de la production finale peut être obtenue, entre autres, par l'application d'engrais est le plus efficace dans la période mai-août. Dans tous les étangs examinés on a constaté que l'application d'engrais augmente la production de plancton. La production finale, c'est-à-dire la croissance des poissons n'a pas été conforme aux prévisions. On a constaté que la croissance totale des carpes était plus forte, quoique l'application d'engrais et d'aliment supplémentaire fût plus petite. La cause en était que la production élevée de plancton n'était pas suffisamment utilisée; il manquait un consommateur de cette espèce d'aliment naturel.

Dans les conditions expérimentales on a pu mieux mettre en évidence la dépendance de la production finale de l'application de différents engrais. Les pièces d'eau fertililisées par les engrais verts et minéraux ont montré la plus grande production.

APPLICATION OF FERTILIZERS AND ITS IMPACT ON TEMPORARY AND PERMANENT FISH STOCKS IN CERTAIN FISH PONDS OF VOJVODINA

Abstract

Some of the fish ponds of Vojvodina (Susek, Jegrička, Futog) were studied under practical working conditions and under experimental conditions. It was observed that the application of various fertilizers, inter alia, leads to increased production. Under conditions in our country, according to our research, the application of fertilizers is most effective during the period from May to August. In all the fish ponds studied it was found that manuring increased the growth of plankton. Final production, that is to say the increase in fish stock, was not commensurate. It was noted that total increase of carp was greatest with the least application of fertilizers or supplementary food. This occurred because the increased quantities of plankton were not sufficiently used; this type of natural food requires the right type of fish consumer.

Under experimental conditions the dependence of final production on the application of a variety of fertilizers was more obvious. Those bodies of water where green manure crops were grown and mineral fertilizers were applied produced the most.

LA FERTILIZACION Y SU INFLUENCIA EN AL AUMENTO DE LA PRODUCCION TEMPORAL Y DEFINITIVA EN CIERTOS ESTANQUES DE VOJVODINA

Extracto

Han sido examinados algunos de los estanques de Vojvodina en las condiciones de servicio (Susek, Jegrička, Futog) y experimentales (Čurug). Se he comprobado que el aumento de la producción final puede realizarse, entre otras formas, mediante la aplicación de abonos diferentes. En nuestras condiciones y según nuestras investigaciones, la aplicación de abonos alcanza su máxima eficacia en el período mayo-agosto. En todos los estanques examinados se ha comprobado que la aplicación de abonos hace aumentar la producción de plancton. La producción final, es decir, el aumento de pescado, no ha sido adecuada. Se ha comprobado que el aumento total de carpas era mayor aunque fuera menor la aplicación de abonos y el alimento suplementario. Ello se debía a que la elevada producción de plancton no era aprovechada suficientemente; faltaba un consumidor de esta clase de alimento natural.

En las condiciones experimentales, se ha podido observar mejor la dependencia de la producción final de la aplicación de diferentes abonos. Las masas de agua abonadas con abonos verdes y minerales han registrado la producción más grande.

1 INTRODUCTION

La présente contribution est un résumé des résultats de l'application de certains engrais sur l'augmentation de la production passagère et finale dans quelques uns de nos étangs. Il est clair qu'on ne peut pas embrasser dans ce court extrait tous les éléments contenus dans les recherches.

Vojvodina est une région aux conditions très favorables pour l'élevage des carpes. Puisqu'il y a déjà des superficies sous eau et qu'il existe la possibilité d'en créer encore, le problème de la productivité est très actuel. L'utilisation d'engrais étant, avec l'alimentation des poissons, une mesure fondamentale pour l'accroissement de la production c'est un problème auquel on doit prêter grande attention. Dans nos étangs, on appliquait jusqu'à présent les expériences d'auteurs étrangers (allemands, soviétiques, etc.) mais, à cause de différentes conditions du climat et de la typologie des étangs, les résultats n'étaient pas toujours satisfaisants. De nombreuses recherches dans la littérature montrent qu'il faut faire des études particulières pour chaque étang comme en a déjà fait dans beaucoup d'étangs en Allemagne, en Union Soviétique, en Israël, en Pologne, en Tchécoslovaquie, etc. (Walter, 1926, 1934; Probst, 1931, 1950; Akatova, 1957; Zadin, 1959; Rodina, 1959; Müller, 1960; Yashouv, 1959, etc.). Dans notre pays on a fait des recherches semblables dans plusieurs étangs en Serbie (Milovanovic, Zivkovic, 1953, 1959, 1963) puis en Croatie (Bojcic et coll., 1961, Asaj, Fijan, Malnar, 1962). Mais leur nombre ne suffit pas encore. C'est pourquoi on a voulu étendre ces recherches à quelques uns des étangs de Vojvodina, dans les conditions naturelles et expérimentales. En pratique on a fait des recherches dans les étangs suivants : Susek, Jegrička et Futog. Expérimentalement on en a fait dans les étangs-frayères et d'engraissement des poissons à Čurug. Ces études ont été faites en 1959, 1960, 1961, 1962 et en 1964. On n'en montrera ici que des résultats sommaires.

2 METHODE DE TRAVAIL

Par l'étude de la production de planoton et de la faune de fond, comme production passagère, et de l'accroissement des carpes, comme production finale, on a contrôlé l'efficacité de l'application de l'engrais. On a fait des contrôles tous les quinze jours, avant et après l'application de l'engrais. Par les pêches d'essai on a vérifié le temps de croissance. On a aussi mesuré spécialement un certain nombre de poissons (50 pièces) en prenant des mesures biométriques élémentaires (longueur, la plus grande hauteur et poids). Les valeurs de la faune de fond et du planoton ont été exprimées en nombre et en poids.

On a fait des recherches expérimentales dans cinq étangs en terre de 305 m^2 de superficie et d'un mètre de profondeur. Les étangs n'étaient pas couverts d'herbes. Toutes les pièces d'eau avaient la même forme et étaient alimentées par l'eau de la même source: la Tissa Morte. La première pièce d'eau servit de contrôle, la seconde ne fut fertilisée qu'avec l'engrais minéral (6,7 kg nitrate d'ammoniaque et 5 kg de superphosphate). L'étang numéro 3 fut fertilisé par 11,5 kg de fumier de ferme, 2 kg de superphosphate et 0,57 kg de nitrate d'ammoniaque. L'étang numéro 4 ne reçut que l'engrais organique sous forme de plantes de prairies (Lolium, Poa, etc.) par 2 kg, selon la méthode de zone (Isakova-Keo, 1954). L'étang numéro 5 reçut l'engrais complet : 2 kg d'herbes de prairie, 5 kg de superphosphate et 6,7 kg de nitrate d'ammoniaque. Tous les étangs furent fertilisés une fois par semaine avec la même dose d'engrais; l'expérience a duré 5 semaines. Sept jours après la première application on a mis dans toutes les pièces d'eau 3 000 exemplaires/ha de carpillons, pesant en moyenne 20 g. A ce moment on a examiné la production du bactérioplancton (méthode décrite par O. Ristić), de zooplancton et contrôlé l'augmentation en poids des carpillons.

3 RESULTATS DE LA RECHERCHE

3.1 L'étang Susek

Cet étang se trouve non loin du Danube. C'est une dépression qu'on utilise depuis 1912 comme étang. Le terrain sur lequel se trouve l'étang est pour la plus gran-

Tableau I

Type et quantité d'engrais utilisé dans l'étang Susek en 1959, 1960 et 1961 (Kg/ha)

Année	Type d'engrais (Kg/ha)			
	Ecume de défécation	Superphosphate	Nitrate ammoniacal	Fumier de ferme
1959	1400	400	-	50
1960	1500	350	112	600
1961	1550	300	91	2000

Tableau II

Biomasse de zooplancton dans l'étang Susek (Valeurs moyennes mg/l, en 1959, 1960 et 1961)

Année	Biomasse de zooplancton (mg/l.)						
	avril	mai	juin	juillet	août	septembre	octobre
1959	4,5	10,2	34,5	42,0	75,6	28,3	15,6
1960	6,7	22,2	40,5	73,2	84,4	35,0	22,8
1961	10,0	28,6	36,4	82,3	93,2	144,3	61,5

Tableau III

Biomasse de la faune de fond dans l'étang Susek (Valeurs moyennes g/m2, en 1959, 1960 et 1961)

Année	Biomasse de la faune de fond (g/m2)						
	avril	mai	juin	juillet	août	septembre	octobre
1959	-	1,9	17,7	20,8	1,49	1,63	3,5
1960	0,93	2,6	18,6	5,6	2,8	1,48	4,1
1961	1,20	1,8	8,2	4,3	3,1	2,08	2,5

Tableau IV

Augmentation en poids des carpes et apport de l'alimentation supplémentaire (kg/ha) dans l'étang Susek, en 1959, 1960 et 1961

Année	Augmentation en poids des carpes kg/ha	Apport de l'aliment supplémentaire kg/ha
1959	1 100	2 745
1960	940	3 168
1961	870	2 850

de part en sol alluvionnaire d'humus. D'après sa structure mécanique, c'est une argile peu sablonneuse. Le sol comporte assez de $CaCO_3$. La réaction du terrain est à peu près pH 7. Le terrain est riche en humus et en azote. L'étang reçoit l'eau du Danube. Pendant toute la période de la recherche on a mis dans l'étang 1 500 pièces/ha de carpes de 60 g de poids moyen.

Les recherches durèrent trois ans et la quantité d'engrais a été différente. L'espèce et la quantité d'engrais sont indiquées dans le Tableau I.

La production du plancton a montré pendant trois ans deux maximums clairement exprimés. Le premier au printemps avec de grands maximums en nombre, mais petits en biomasse, et l'autre au mois d'août, avec le maximum de biomasse. Pendant les trois années de l'étude dans cet étang, c'est au mois d'août que la production de zooplancton était maximum. Des valeurs moyennes pour la biomasse de zooplancton se trouvent au Tableau II.

La production de la faune de fond montre aussi des variations saisonnières, ce qui est en relation avec la biologie des organismes qui la composent (Chironomidae) et avec l'intensité de l'alimentation des carpes. La production de la faune de fond atteint les valeurs maximums au cours des mois de juin-juillet (voir Tableau III).

L'augmentation totale des carpes et la dépense en aliment supplémentaire (kg/ha) dans les périodes mentionnées figurent au Tableau IV.

3.2 L'étang Jegrička

Cet étang représente le lit endigué de la rivière Jegrička dans son cours inférieur. Comme il n'est pas possible, en toutes saisons de s'alimenter en eau de la rivière Jegrička, on utilise le puits de la station. Cet étang se trouve dans une région où la quantité moyenne des précipitations annuelles est inférieure aux valeurs moyennes des autres régions de Vojvodina. La moyenne annuelle de température est de 10,9°C, ce qui représente une moyenne un peu inférieur à celle de Vojvodina. La base géologique de ce terrain est le loess avec beaucoup de concrétions calcaires et des sédiments de calcaire tendre. D'après le type du sol c'est un terrain marécageux et d'après sa structure c'est une glaise. La réaction du sol dans les sédiments supérieurs est un peu acide et on peut conclure que ce terrain se trouve dans un processus de dégradation. L'étang est utilisé depuis 1957. On y a fait des recherches en 1964. Dans l'étang il y avait 900 spécimens/ha de carpes de 154 g de poids moyen. L'apport total de l'engrais, d'aliment supplémentaire et la production de la faune de fond et du plancton sont indiqués dans le Tableau V.

3.3 L'étang Futog

C'est un étang encore jeune qui existe depuis deux ans. Il se situe sur le terrain de la rive gauche du Danube. D'après la structure mécanique du sol, on y trouve des alluvions sablonneuses, des alluvions de vase et de marais, un terreau marécageux et le sol minéral de marais. L'étang est assez largement couvert de roseaux, ce qui crée des difficultés dans l'application des mesures techniques de pisciculture. La technique de production est ici extensive.

Les engrais appliqués et la production de cet étang sont indiqués dans le Tableau VI.

3.4 Recherches dans les étangs expérimentaux

Il a déjà été mentionné que dans chacune des pièces d'eau on applique une méthode différente de fertilisation et on suit l'effet par le développement de bactérioplancton, puis de zooplancton et par la croissance des carpillons.

L'étang numéro 1 était le contrôle et on n'a pu y observer de grandes variations, ni du bactérioplancton, ni du zooplancton. Le bactérioplancton avait ici la plus faible densité et la biomasse de zooplancton variait entre 36-52 mg/l. Il ne s'y produisit

Tableau V

Apport d'engrais, d'aliment supplémentaire (kg/ha)
Production de zooplancton, et de faune de fond (valeur maximum mg/l et g/m2)
Croissance totale des carpes (kg/ha) dans l'étang Jegrička en 1964

Engrais	kg/ha	Aliment supplémentaire (kg/ha)
Ecume de défécation Superphosphate Fumier de ferme	1 352 401 523	1 920
Biomasse de zooplancton mg/l	85,5	Biomasse de la faune de fond g/m2 6,30
Croissance des carpes	850	

Tableau VI

Apports en engrais et en aliment supplémentaire (kg/ha)
Production de zooplancton et de faune de fond (valeur max. mg/l et g/m2)
Accroissement des carpes dans l'étang Futog en 1964

Engrais Superphosphate kg/ha	Aliment supplémentaire kg/ha	Biomasse de zooplancton mg/l	Biomasse de la faune de fond g/m2
25	485	51,25	8,80
Accroissement des carpes (kg/ha : 450)			

Tableau VII

Valeurs moyennes de bactério- et zooplancton
Augmentation des carpeaux dans chaque pièce d'eau (Curug, 1964)

Etangs No	Moyennes de bactérioplancton 000/ml		Moyennes de zooplancton 000/ml		Augmentation du poids des carpillons par rapport au poids primitif (x)
	Nombre	% de contrôle	Nombre	% de contrôle	
1	2,6x10^5	100%	4,1x10^3	100%	2,5
2	4,1x10^5	157%	4,9x10^3	120%	3,3
3	6,4x10^5	242%	5,5x10^3	134%	3,9
4	6,5x10^5	247%	5,6x10^3	135%	5,0
5	20,0x10^5	766%	8,0x10^3	195%	7,0

pas de développement en masse des Cladocères, ni des Copépodes; le nombre de Rotateurs s'est maintenu presque pendant tout le temps à un niveau assez élevé. Dans les autres pièces d'eau on a pu constater une variation en nombre du bactérioplancton et de zooplancton de sorte que plusieurs jours après la fertilisation on observa l'augmentation du bactérioplancton et, un peu plus tard, celle du zooplancton. Le maximum du bactérioplancton précéda toujours celui du zooplancton et après ce dernier la quantité de bactérioplancton diminuait brusquement. La dynamique générale du bactérioplancton et du zooplancton dans les pièces d'eau est exposée dans le Tableau VII.

4 ANALYSE DES RESULTATS OBTENUS

Il est clair que dans les conditions pratiques on ne peut pas suivre avec certitude l'effet de l'engrais appliqué, à cause de plusieurs facteurs et des difficultés techniques, mais les résultats de la recherche peuvent quand même fournir quelques indications. On fait toutes ces mesures pour augmenter la production finale de poisson dans un étang, ce qu'on réussit indirectement en influant sur la production passagère (plancton et faune du fond) qui représente la source naturelle de l'alimentation dans les étangs. Plusieurs auteurs dans la littérature disent qu'on peut augmenter la croissance jusqu'à 77% par l'application d'engrais (Schäperclaus, 1942). En Israël après plusieurs années de recherche on a constaté que cette augmentation peut être 732% (Hepher, 1962; 1963). Pendant les trois ans de nos recherches à Susek la quantité de superphosphate a été à peu près pareille. Il y avait une différence entre nitrate ammoniacal et fumier de ferme. L'analyse de la quantité d'engrais et de l'augmentation du poisson montre qu'en 1959 l'augmentation a été la plus élevée. Alors en n'a employé que 400 kg/ha de superphosphate, 50 kg/ha de fumier de ferme. Par contre, en 1961 quand on a employé 300 kg/ha de superphosphate, 91 kg/ha de fumier de ferme. Par contre, en 1961 quand on a employé 300 kg/ha de superphosphate, 91 kg/ha de nitrate ammoniacal et 2 000 kg/ha de fumier de ferme, l'augmentation totale était de plus de 200 kg/ha moindre qu'en 1959. Ici, on doit prendre en considération tous les facteurs, mais on peut dire cependant, que l'influence de la fertilisation sur l'augmentation est limitée. C'est-à-dire que, si on compare la quantité d'engrais et la production de plancton, on verra que celle-ci est plus grande si on augmente la quantité d'engrais. Mais, puisque la carpe de cette taille utilise peu de plancton pour sa nourriture (presque rien), l'augmentation de cette production n'a pas d'influence fondamentale sur la production finale. Par contre, quand il s'agit de la faune de fond on peut remarquer une dépendance plus grande. Les plus grandes valeurs observées dans la production de la faune benthique à Susek l'ont été en 1959. C'est alors qu'on a constaté le plus grand accroissement des carpes quoique la quantité d'engrais et d'aliment supplémentaire furent moindres que les années suivantes. On pourrait dire la même chose pour les étangs Jegrička et Futog.

Quand on étudie l'effet de la fertilisation dans les étangs expérimentaux on constate, comme Rodina (1952) en Union Soviétique, que le développement plus intense du zooplancton dépend de l'augmentation des populations de bactéries. Les différentes productions de bactéries, et de zooplancton dépendent des différentes combinaisons d'engrais. La combinaison de l'engrais végétal, sous forme d'herbe de prairie, avec l'engrais minéral a causé la plus forte production. Les engrais minéraux donnent au commencement une production plus faible (les 4 premières semaines) et plus tard on a constaté une croissance plus rapide. Si on suit la dynamique du bactérioplancton et de certains groupes du zooplancton, on voit clairement la relation directe entre bactérioplancton et Cladocères. Au cours de ces essais on a remarqué que l'augmentation des carpillons était beaucoup plus grande si la production des bactéries et de zooplancton était plus grande. Il en est ainsi parce que la carpe de cette taille consomme le plancton en grande quantité, surtout les Cladocères, apparus en masse dans les étangs ayant reçu des engrais complexes. En observant ces résultats, on voit nettement qu'il faut tenir compte d'une série de composantes pour augmenter la production finale. Dans beaucoup de pays on travaille à l'introduction de nouvelles espèces pour la meilleure utilisation de l'alimentation naturelle, mais chez nous on n'a, jusqu'à présent, pas fait beaucoup de progrès dans ce domaine.

5 REFERENCES

Akatova, N.A., Zooplancton prudov rybtsovo-shemainogo pitomnika. Trudy zool.Inst.,
1959 Leningr., 26:257-95

Asaj, A., N. Fijan et J. Malnar, Neki podaci o kolicini dusika, forfora i kalcija u vodi
1962 razlicito gnojenih ribnjaka. Vet.Arh., 32(3-4):83-91

Bojcić, C. et al., Proizvodni pokusi za povecanje prinosa na saranskim ribnjacima u 1960
1961 god. Ribarst.Yugosl., 16(1):3-7

Fijan, N. et al., Rezultati trogodisnjih pokusa o gnojenju saranskih ribnjaka u prakticnim
1964 uslovima. Ribarst.Yugosl., 19(5-6):123-38

Hepher, B., Ten years of research in fish ponds fertilization in Israel. 1. The effect
1962 of fertilization on fish yields. Bamidgeh, 14(2):29-38

Isakova-Keo, M.N., Zonalni metod vyrashchivaniia zhivykh kormov i znacheniia dlia prudovykh
1950 khoziaistv i rybovodnykh zavodov. Vest.leningr.gos.Univ., (8)

Milovanovic, D. et Z. Zivkovic, Ispitivanja planktonske produkcije u ribnjacima Ecke.
1953 Zborn.Rad.Inst.Ekol.Biogeoyr, (3)

__________, Planktonska produckcija u ribnjaku Zivaca. Zborn.Rad.biol.Inst.NR Srb., 2
1959

__________, Sastav i dinamika planktona u ribnjaku Jegricka u 1959 i 1960. Zborn.Rad.
1963 biol.Inst.NR Srb., 6(4)

Müller, W., Untersuchung über Nachwirkung im Vorjahr gegebener Phosphatdüng in Teichen.
1960 Z.Fisch., 9(7)

Probst, E., Teichdüngung. Allg.Fisch.-Ztg, (8/9)
1950

Pujin, V., Zooplanktonska produkcija ribnjaka u Susek. Letopis naucnih radova Poljoprivrednog fakulteta u Novom Sadu, sv.6, 42 p.
1962

Ristic, O. et V. Pujin, Uzahamni odnos zooplanktona i bakterioplanktona pri razlicitim
1964 nacinima djubrenja. Mikrobiologia, 1(1):121-32

Rodina, A.G., Dinamika bakterijalnoj biomasi pri ispolzovaniji zelenovo udobrenija v
1952 rybovodnyh prudah. Dokl.Akad.Nauk, SSSR, 24

Schäperclaus, W., Lehrbuch der Teichwirtschaft. Berlin, Paul Parey, 582 p.
1961

Walter, E., Die Versuche 1925 in der bayerischen teichwirtschaftlichen Versuchstation
1926 Wielenbach. Fischereiztg., 29

__________, Grundlage der allgemeinen fischereilichen Produktionslehre. Handb.Binnenfisch.Mitteleurop., 4
1934

Yashouv, A., Studies on the productivity of fish ponds. 1. Carrying capacity. Proc.gen.
1959 Fish.Coun.Medit., 5:409-19

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II/E-6

FERTILIZATION OF FISH PONDS WITH TRACE ELEMENT MANGANESE FOR INCREASED PRODUCTION OF PLANKTON

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Abstract

For increased production of plankton in fish ponds a series of experiments were conducted in cement cisterns and in ponds using trace elements like manganese, copper and iron along with phosphatic fertilizer. Two soil types were used in this investigation; one a slightly acidic soil, high in phosphorus but low in manganese and the other also with a slightly acidic reaction but low in phosphorus and relatively high in manganese. The results showed that both the soils responded fairly to treatment with manganese showing an increase of plankton weight by about 14 percent due to manganese alone. In the case of high phosphorus and low manganese soil the additional increase of plankton for a dose of 1 kg/ha of manganese was 16.4 percent, which compares well with an increase of 14.6 percent by 20 kg/ha of P_2O_5. In the other soil with low phosphorus and high manganese the additional increase in plankton weight due to manganese was 21 percent against 48 percent by phosphate alone, but when the effect of phosphate plus manganese was compared with that of phosphate minus manganese, it was observed that both the soil types exhibited about 14 percent increase in plankton weight due to manganese alone showing that for the range of water soluble manganese in soil from 0.25 to 2.8 ppm and soluble manganese in water from 0.25 to 2.8 ppm and soluble manganese in water from 0.001 to 0.02 ppm, the degree of response was rather independent of manganese status of soil and water. The effect of incorporation of two other trace elements, copper and iron, at the same dose did not show any marked increase in production of plankton.

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FERTILISATION DES ETANGS DE PISCICULTURE AVEC DU MANGANESE A FAIBLE DOSE POUR ACCROITRE LA PRODUCTION DE PLANCTON

Résumé

Pour accroître la production de plancton dans les étangs de pisciculture une série d'expériences ont été faites dans des citernes cimentées et dans des étangs avec des oligo-éléments tels que le manganèse, le cuivre et le fer associés à des engrais phosphatés. Les expériences ont été pratiquées sur deux types de sol: l'un légèrement acide, à teneur élevée en phosphore mais faible en manganèse, l'autre également légèrement acide mais ayant une faible teneur en phosphore et une teneur relativement forte en manganèse. Les résultats montrent que dans les deux cas le traitement au manganèse a donné des résultats positifs puisque l'adjonction de ce seul élément a provoqué une augmentation en poids du plancton d'environ 14 pour cent. Dans le cas du sol à haute teneur en phosphore et à faible teneur en manganèse, l'augmentation de plancton pour une dose de 1 kg/ha de manganèse était de 16,4 pour cent, ce qui se compare favorablement à l'augmentation de 14,6 pour cent obtenue avec 20 kg/ha de P_2O_5. Dans l'autre sol, celui à faible teneur en phosphore et à teneur élevée en manganèse, l'augmentation pondinale du plancton était de 21 pour cent avec le manganèse alors qu'il atteignait 48 pour cent avec le phosphate employé seul, mais en comparant les effets obtenus avec phosphate plus manganèse à ceux obtenus avec phosphate moins manganèse on a constaté, avec les deux types de sol, une augmentation d'environ 14 pour cent du poids du plancton attribuable au manganèse seul. Ainsi, lorsque la teneur du sol en manganèse soluble dans l'eau varie entre 0,25 et 2,8 ppm et que la teneur de l'eau en manganèse soluble se situe entre 0,001 à 0,02 ppm le degré de réaction est relativement indépendant de la quantité de manganèse contenue dans le sol et dans l'eau. L'incorporation de deux autres oligo-éléments, cuivre et fer, à des doses analogues, n'a pas eu d'effet sensible sur la production de plancton.

FERTILIZACION DE LOS ESTANQUES PISCICOLAS CON MANGANESO COMO OLIOGOELEMENTO PARA EL AUMENTO DE LA PRODUCCION DE PLANCTON

Extracto

Para elevar la producción de plancton en los estanques piscícolas se llevaron a cabo una serie de experimentos en cisternas de cemento y en estanques utilizando oligoelementos como el manganeso, el cobre y el hierro junto con fertilizantes fosfáticos. Se usaron dos tipos de suelos en esta investigación: uno ligeramente ácido con elevada cantidad de fósforo pero con poco manganeso, y el otro también con una reacción ligeramente ácida pero con poco fósforo y relativamente elevada proporción de manganeso. Los resultados demostraron que ambos suelos respondieron bastante bien al tratamiento con manganeso, mostrando un aumento del peso del plancton del 14 por ciento, aproximadamente, debido solamente al manganeso. En el caso del suelo con elevadas cantidades de fósforo y poco manganeso, el aumento adicional de plancton para una dosis de 1 kg/ha. de manganeso fué del 16,4 por ciento, lo cual se aproxima mucho al aumento de 14,6 por ciento por 20 kg/ha. de P_2O_5. En el otro suelo con poco fósforo y elevada proporción de manganeso, el aumento adicional del peso del plancton debido al manganeso fué del 21 por ciento frente al 48 por ciento con fósforo solamente, pero cuando el efecto del fosfato unido al manganeso, se comparó con el del fosfato sin manganeso, se observó que ambos tipos de suelo exhibían alrededor de un 14 por ciento de aumento en el peso del plancton debido al manganeso solamente, mostrando que para los márgenes de variación de manganeso hidrosoluble en el suelo de 0,25 a 2,8 ppm y de manganeso en el agua de 0,001 a 0,02 ppm, el grado de respuesta era bastante independiente de la cantidad de manganeso en el suelo y en el agua. El efecto de la incorporación de otros dos oligoelementos, cobre y hierro, a las mismas dosis, no mostró ningún aumento sensible de la producción de placnton.

1 INTRODUCTION

Increased production of phyto-plankton, or more precisely speaking, acceleration of the rate of primary production in fish ponds is of vital importance in successful fish culture operations. Depending primarily on the fertility status of water and soil in a pond for their growth, planktonic algae form the first and important link in the food chain for fish. Natural and inherent fertility of ponds has often been found to be unsatisfactory due to deficiency in one or more of the nutrient elements in soil and water. Correction of this deficient condition by the application of fertilizers in proper form and in optimal quantities forms an important problem for investigation. Though a considerable amount of work has been done with fertilizer elements like nitrogen, phosphorus, potassium and calcium (Mortimer,1954) practically very little work has been done with micro-elements like manganese, copper, iron, boron, vanadium, molybdenum, etc. Two obvious reasons are responsible for it. Firstly, the importance of these elements in plant and animal nutrition has been recognized only in comparatively recent years; secondly the function of these elements in metabolic processes still remains obscure in many cases and so more concerted efforts have been directed towards elucidating the role of micro-nutrients in biochemical processes in plants and animals rather than conducting field experiments to study growth promoting properties.

Among the micro-elements probably manganese has been the subject of more extensive investigations. In the early part of this century evidence was presented by McHargue (1922) and others to show that manganese must be regarded as essential for plant growth. Since then so many investigators have recorded observations on manganese requirements of higher plants from different parts of the world. In India Patnaik (1955) from a series of sand culture studies showed that in the absence of manganese, growth of rice plants was poor, the plants were lighter green in colour and the leaves were spotted in appearance. When manganese was added at a concentration of 1 ppm the yield was nearly doubled, but a concentration over 5 ppm proved toxic, the plants becoming stunted and chlorotic. In more recent years the role of micro-nutrients in plant metabolism has been studied under laboratory conditions by many workers (Arnon, 1958; Pirson, 1958; Brown et al.,1958; Eyster et al., 1958) using planktonic algae of simple structure like Ankistrodesmus, Scenedesmus and Chlorella sp. It is now almost well established that manganese plays an important role both in photosynthesis and in heterotrophic growth of phyto-plankton. The requirement of manganese for entirely autotrophic physiological processes is comparatively much higher than that required for heterotrophic growth. It was shown that under laboratory conditions, growth of phyto-plankton (Scenedesmus) estimated by cell count, packed cell volume and dry weight, was arrested under manganese deficient condition. For aquatic micro-plants earlier work of Hopkins (1930a, b and c), Clark and Fly (1930), Clark (1933) and Saegar (1933) showed that under laboratory conditions addition of manganese in culture solution increased the growth of Chlorella, Lemna minor and five other species of Lemnaceae, to a marked extent.

In an attempt to explore the possibility of using the existing laboratory findings for increasing production of plankton in fish ponds a series of experiments were conducted in laboratory, in cement cisterns under semi-field conditions and in fish ponds under purely field conditions. The results of these experiments are presented and discussed in this paper.

2 EXPERIMENTS

In the case of land plants there are recognized deficiency symptoms specific for individual trace elements which can be of diagnostic help. Such deficiency symptoms under extremely low concentrations of the element under laboratory conditions have been recorded for planktonic algae, but under field conditions manganese concentration in water is not likely to show such extremely low values. So to know what actually constitutes the deficient condition for a particular trace element, we have to depend entirely on the concentration of that element in soil and water and study the response of the soil type to treatment with salts of that element using growth of plankton as an index of response.

In preliminary observations on the manganese status of soil and water of fish ponds in Orissa, the authors (Banerjee and Banerjea - unpublished) have shown that the manganese content of soil in various forms (water soluble, exchangeable, reducible, total) and the soluble manganese in water varies from pond to pond even within a radius of forty miles. Of the different forms of manganese, water soluble manganese in soil showed highly significant correlation with manganese in water. Among the fish ponds studied it was noticed that soluble manganese in water and soil was very poor in Jobra farm showing an average of 0.014 ppm and 0.420 ppm respectively, most of the ponds having a concentration of 0.005 ppm in water, while Chaudwar farm had relatively higher manganese concentration in water and soil with an average of 0.073 ppm in water and 2.520 ppm in soil. These two soils representing low and high manganese status of pond soils studied so far, were selected for the experimental study.

The experiments were conducted in three series. In the first series, the low manganese soil of the Jobra farm was studied in cement cisterns under semi-field conditions using manganese as a trace element. The second series of experiments were undertaken in small ponds in Chaudwar fish farm, having a relatively high concentration of manganese in water and in soil, using only manganese as a trace element. In the third series of experiments a combination of three trace elements, viz., manganese, copper and iron was used. In all the experiments a basal dose of superphosphate at the rate of 20 Kg of P_2O_5 per hectare was added so that phosphorus deficiency in soil may not act as a limiting factor in plankton production.

2.1 Experiment I

This experiment was carried out in six cement cisterns of approximate dimensions, 1.0 m x 0.7 m x 1.0 m (length x breadth x depth), and about 0.5 m^3 capacity. The cisterns were drained, cleared and allowed to dry. A bottom substratum of about 15 cm thickness of soil from a pond in the Jobra fish farm was provided in each cistern. The soil was collected in bulk, dried, powdered and spread uniformly on the bottom of the cisterns. They were then refilled with water from the parent pond. A week's time was allowed for the establishment of equilibrium conditions between soil and water. In order to ensure sufficient seed for plankton, each cistern was inoculated with a concentrated plankton sample of about 5 cc collected from the parent pond. A week later manuring was done. Two cisterns were kept as control without any treatment; two were treated with superphosphate alone at the rate of 100 Kg/ha, equivalent to 20 Kg P_2O_5 per hectare, while the remaining two were manured with superphosphate at the rate of 100 Kg/ha + manganous sulphate ($MnSO_4,H_2O$) at the rate of 3 Kg/ha, equivalent to 1 Kg Mn per hectare, so that the effective concentration of added manganese on volume basis was 0.14 ppm. The fertilizers were mixed with a quantity of mud from the parent pond, formed into small pellets and distributed uniformly all over the water area. Soil samples were collected and analysed before treatment, three months after treatment and finally after six months when the experiment was concluded. Water samples for chemical analysis and plankton analysis were collected fortnightly. Plankton samples were collected by straining 10 litres of water from 20 different places through a bolting silk net, and this being only 2 percent of the total volume of water, the plankton concentration in the cistern was not affected appreciably. From each cistern 250 cc of water was collected for chemical analysis, the loss of water due to this and due to evaporation was made up by adding water from the pond strained through a bolting silk net. The plankton sample after being strained was concentrated to a volume of 20 cc and a uniform mixture was obtained by thorough shaking from which 1 cc was preserved in 4 percent formalin for estimating the percentage of zoo- and phyto-plankton and also to determine the predominant plankters. The remaining portion was centrifuged, the supernatant liquid decanted and the sample filtered through a quantitative filter paper (Whatman No.42). After washing the residue with distilled water, it was transferred to a tared platinum basin, dried in an electric oven at a constant temperature of 103°C and weighed to a constant

TABLE I(a)

Water quality of treated and untreated cisterns[1]

	Control (No treatment)				20 Kg P_2O_5 per hectare			
Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
December	8.1	81	0.04	0.001	8.1	75	0.05	0.001
January	8.7	78	0.06	0.001	8.7	77	0.10	0.001
February	8.8	71	0.06	0.001	9.3	61	0.15	0.001
March	8.6	85	0.08	0.001	8.7	70	0.28	0.002
April	8.8	82	0.11	0.001	9.0	73	0.45	0.002
May	8.8	80	0.32	0.001	8.8	86	0.48	0.002
Average	8.6	80	0.11	0.001	8.8	74	0.25	0.0015

	20 Kg P_2O_5 + 1Kg Mn per hectare			
Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
December	8.2	76	0.04	0.001
January	8.7	87	0.06	0.001
February	8.9	81	0.08	0.002
March	8.7	93	0.12	0.003
April	8.6	103	0.40	0.003
May	8.9	84	0.51	0.003
Average	8.7	87	0.20	0.0022

[1] Expressed in ppm, except pH

TABLE I (b)

Soil condition of treated and untreated cisterns [1]

Control (no treatment)

Month	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
December	6.3	1260	120	455	214	550	0.22
March	6.4	1280	130	440	230	490	0.24
June	6.3	1250	150	450	252	519	0.28
Average	6.3	1262	133	448	232	517	0.25

20 Kg P_2O_5 per hectare

	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
December	6.4	1240	120	450	218	570	0.24
March	6.6	1300	140	450	239	570	0.25
June	6.5	1260	150	465	262	580	0.28
Average	6.5	1267	137	455	240	573	0.26

20 Kg P_2O_5 + 1 Kg Mn per hectare

	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
December	6.4	1260	130	460	220	570	0.23
March	6.5	1260	140	445	240	580	0.26
June	6.3	1280	150	445	262	580	0.31
Average	6.4	1267	140	453	241	577	0.27

[1] Expressed in ppm, except pH

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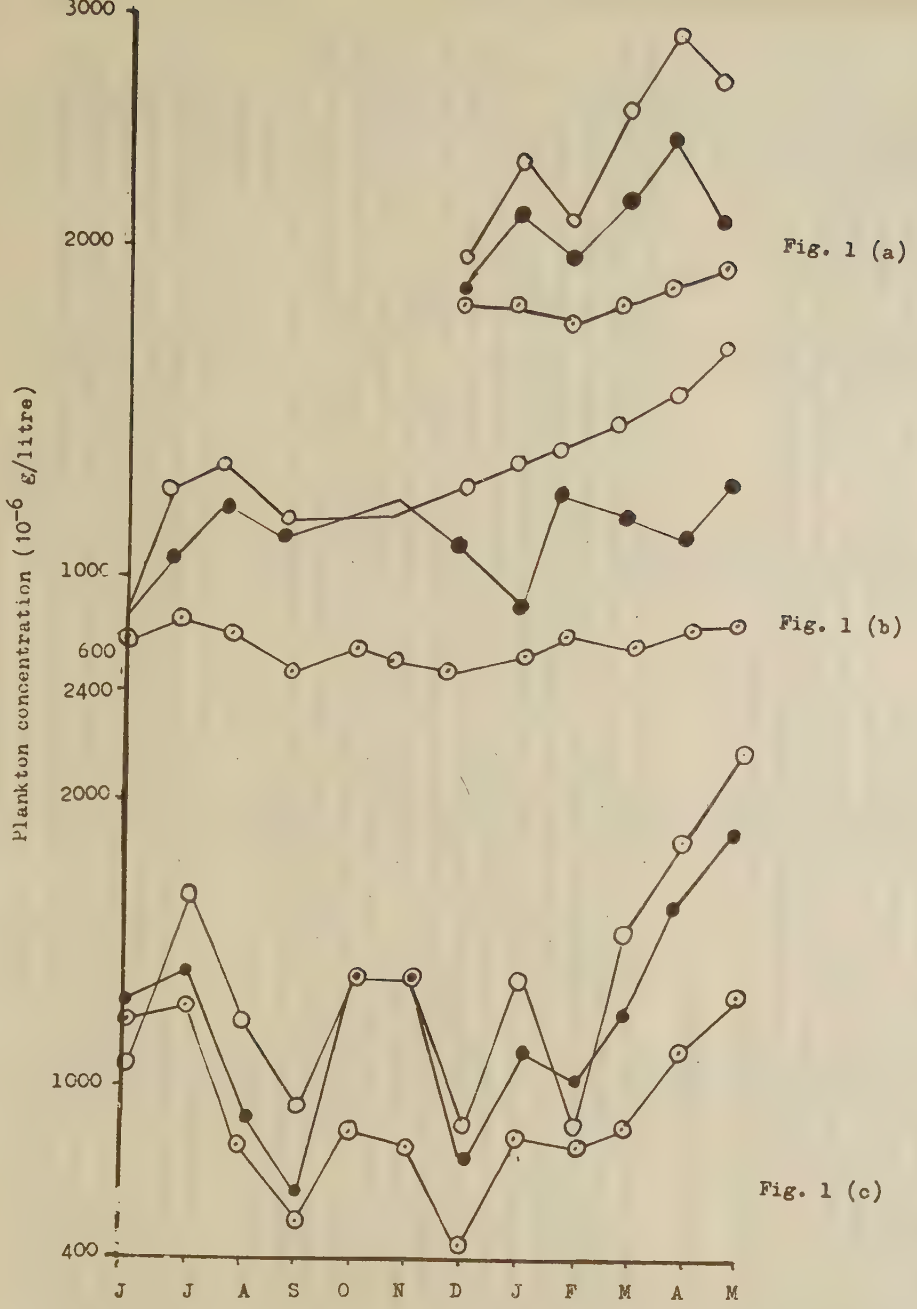
TABLE 1 (c)

Plankton concentrations in treated and untreated cisterns

Control (No treatment)					
PLANKTON					
Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
December	1875	32	Cladophora, Scenedesmus	68	Diaptomus, Cladocerans
January	1875	54	Cosmarium, Amphora	46	Nauplii, Conochilus
February	1825	36	Volvox, Scenedesmus	64	Keratella, Cladocerans
March	1925	74	Microcystis, Closterium	26	Cyclops, Nauplii
April	2000	88	Volvox, Microcystis	12	Copepods, Rotifers
May	2025	56	Volvox, Anabaena	44	Copepods, Rotifers
Average	1921				
Increase over control (%)	-				
20 Kg P_2O_5 per hectare					
PLANKTON					
	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
December	1925	40	Scenedesmus, Spirogyra	60	Copepods, Rotifers
January	2175	62	Oscillatoria, Pandorina	38	Diaptomus, Rotifers
February	2040	26	Volvox, Spirogyra	74	Copepods, Cladocerans
March	2325	80	Microcystis, Volvox	20	Diaptomus, Nauplii
April	2525	92	Microcystis, Oscillatoria	8	Brachionus, Keratella
May	2225	62	Volvox, Oscillatoria	38	Cyclops, Arcella
Average	2203				
Increase over control (%)	14.6				
20 Kg P_2O_5 + 1 Kg Mn per hectare					
PLANKTON					
	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
December	2050	36	Spirogyra, Cladophora	64	Rotifers, Copepods
January	2400	80	Volvox, Spirogyra	20	Cladocerans, Cyclops
February	2225	22	Scenedesmus, Lyngbia	78	Brachionus, Diaptomus
March	2600	82	Microcystis, Oscillatoria	18	Cladocerans, Rotifers
April	3000	95	Microcystis, Volvox	5	Nauplii, Brachionus
May	2825	72	Microcystis, Anabaena	28	Cladocerans, Rotifers
Average	2517				
Increase over control (%)	31.0				
Increase over phosphate treatment(%)	14.2				

$\gamma = 10^{-6}$g



F.g. 1 Fluctuations in plankton concentrations for the control and treated series

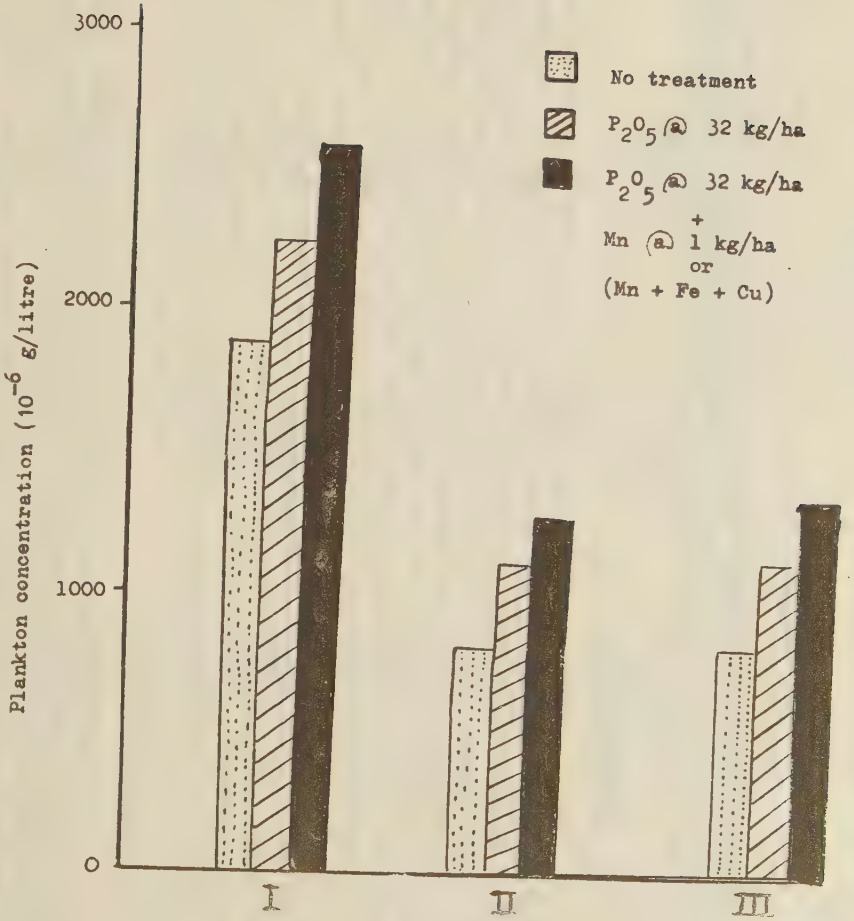


Fig. 2 Average plankton concentration for different treatments

weight. The monthly averages for water and plankton analysis are given in Tables I(a) and I(c), while Table I(b) presents the results of periodic examination of soil. The duration of the experiment was six months, as indicated earlier.

2.2 Experiment II

The second series of experiments was conducted in small nursery ponds at Chaudwar fish farm, ranging in size from 0.048 to 0.076 hectare. The ponds though perennial in nature retained only about one meter of water during the summer months of May-June, when they were cleared of all the previous stock of fish by repeated nettings with a fine-meshed net. Submerged and floating vegetation, as well as marginal grasses were completely removed by manual labour. As the ponds had high bunds on all sides, very little water entered them from the catchment area. After making collections of soil, water and plankton in the month of June during pre-treatment condition, two of the ponds were treated with superphosphate alone at the rate of 20 Kg P_2O_5/ha and two were treated with superphosphate at the rate of 20 Kg P_2O_5/ha + manganous sulphate at the rate of 1 Kg mn/ha, during the last week of June. The remaining two ponds were kept as control without any treatment. Regular periodic observations on soil condition, water quality and plankton population were continued for one complete year. The data are presented in Tables II(a) to II(c).

2.3 Experiment III

In the third series of experiments all the procedures were the same as in the second series, excepting that three trace elements, viz., manganese, copper and iron were used in combination at the rate of 1 Kg mn/ha + 1 Kg cu/ha + Kg fe/ha instead of only 1 Kg mn/ha, added in the second series. Manganous sulphate, copper sulphate and ferrous sulphate were used for the respective elements. As all the ponds had nearly one meter of water during the period of treatment, the effective concentrations of added trace elements were 0.1 ppm on volume basis. The observations on plankton concentration, water quality and soil condition were continued for one year and the data are presented in Tables III(a) to III(c). Fluctuations in plankton concentrations for the control and treated series are given in Fig. 1, while the variation in average plankton concentrations for the control and treated series in different experiments are shown in Fig. 2.

3 RESULTS AND DISCUSSION

That trace elements added to fish ponds along with fertilizers might possibly increase plankton production was probably first pointed out by Mehring (1918). While explaining the variable behaviour of potassium fertilizers, he suggested that presence of trace elements in kainite might be responsible for its beneficial effect. His remark, however, received only scant attention by workers on pond fertilization. Swingle (1947) during his work on pond fertilization at Alabama found that results are quite unpredictable. Sometimes fertilization was followed by delayed algal growth and attempts to hasten production of algae in such cases by the addition of minor elements such as zinc, manganese, boron, iron and copper were all without any effect. In the absence of any knowledge regarding the concentration of these elements in the soil and water phases, these findings did not lead to any definite conclusions. Harvey (1947) working with marine plankton found that as little as 0.0001 ppm of manganese increased the growth of some forms of planktonic algae. Experiments conducted by Henderson (1949) in concrete pools showed that manganese may be of some help in causing and maintaining water blooms.

In the present study the results of experiments in the first series carried out in cement cisterns under more controlled conditions showed that both treatment with superphosphate alone and with superphosphate + manganese sulphate result in definite increase in weight of plankton, but the increase in the latter case was higher than in the former (Table I(a) and Fig. 1(a)). Plankton concentrations in all the cisterns showed irregular fluctuations during the period of experiment, but the total weight of plankton produced by

TABLE II (a)

Water quality of treated and untreated ponds[1]

Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
Control (No treatment)				
June	8.0	92	0.12	0.03
July	8.4	109	0.08	0.02
August	8.0	82	0.04	0.02
September	7.2	70	0.03	0.01
October	7.2	68	0.07	0.01
November	7.1	56	0.03	0.01
December	7.0	52	0.02	0.01
January	7.4	83	0.02	0.01
February	8.2	104	0.04	0.02
March	8.4	105	0.09	0.02
April	8.4	110	0.015	0.04
May	8.2	104	0.017	0.04
Average	7.8	86	0.07	0.02
20 Kg P_2O_5 per hectare				
	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
June	7.9	76	0.14	0.04
July	8.2	72	0.09	0.02
August	7.7	66	0.03	0.02
September	7.3	62	0.03	0.01
October	7.3	62	0.07	0.01
November	7.1	62	0.05	0.01
December	7.1	58	0.02	0.01
January	7.4	76	0.02	0.02
February	7.5	84	0.04	0.02
March	7.6	86	0.17	0.04
April	7.7	92	0.18	0.04
May	7.6	94	0.23	0.06
Average	7.5	74	0.09	0.02
20 Kg P_2O_5 + 1 Kg per hectare				
	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
June	8.0	80	0.13	0.03
July	8.5	84	0.09	0.05
August	7.7	68	0.10	0.03
September	7.4	73	0.02	0.02
October	7.5	75	0.02	0.02
November	7.4	74	0.04	0.01
December	7.4	76	0.02	0.01
January	7.8	82	0.02	0.01
February	7.9	82	0.03	0.03
March	7.9	84	0.15	0.04
April	8.0	84	0.22	0.04
May	8.1	86	0.13	0.04
Average	7.8	79	0.08	0.03

[1] Expressed in mg/litre, except pH

TABLE II (b)

Soil condition of treated and untreated ponds [1]

Control (No treatment)

Month	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.6	680	36	790	396	627	3.1
July	6.7	650	30	760	375	630	2.8
December	6.7	640	31	710	345	625	2.4
June	6.5	650	34	770	380	630	3.0
Average	6.6	655	33	757	371	628	2.8

20 Kg P_2O_5 per hectare

	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.6	680	32	780	372	645	3.6
July	6.7	660	40	748	352	640	3.2
December	6.9	640	32	700	330	630	2.8
June	6.6	660	36	770	360	625	3.8
Average	6.7	660	35	749	353	632	3.3

20 Kg P_2O_5 + 1 Kg Mn per hectare

	pH	P_2O_5		N		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.5	660	32	760	380	640	3.2
July	6.6	680	42	740	368	625	3.6
December	6.8	670	30	770	322	610	3.0
June	6.5	650	36	750	382	640	3.9
Average	6.6	665	35	755	363	629	3.4

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[1] Expressed in ppm, except pH

TABLE II (c)

Plankton concentrations in treated and untreated ponds

Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
Control (No treatment)					
PLANKTON					
June	778	56	Ulothrix, Spirogyra	44	Copepods, Rotifers
July	822	50	Oscillatoria, Spirogyra	50	Cladocerans, Rotifers
August	778	28	Anabaena, Amphora	72	Diaptomus, Cladocerans
September	620	12	Cladophora, Scenedesmus	88	Copepods, Cladocerans
October	720	36	Oscillatoria, Scenedesmus	64	Cladocerans, Diaptomus
November	650	24	Amphora, Closterium	76	Copepods, Rotifers
December	600	20	Cosmarium, Ulothrix	80	Cladocerans, Rotifers
January	738	56	Volvox, Scenedesmus	44	Brachionus, Copepods
February	822	62	Oscillatoria, Anabaena	38	Rotifers, Keratella
March	744	70	Volvox, Anabaena	30	Cladocerans, Nauplii
April	860	60	Microcystis, Oscillatoria	40	Brachionus, Copepods
May	844	68	Microcystis, Volvox	32	Difflugia, Copepods
Average	748				
Increase over control (%)	-				
20 Kg P_2O_5 per hectare					
PLANKTON					
	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
June	835	36	Anabaena, Amphora	64	Diaptomus, Nauplii
July	1010	72	Oscillatoria, Microcystis	28	Cladocerans, Difflugia
August	1140	66	Volvox, Pandorina	34	Cladocerans, Conochillus
September	1000	42	Lyngbia, Oscillatoria	58	Rotifers, Brachionus
October	1065	42	Oscillatoria, Scenedesmus	58	Keratella, Nauplii
November	1140	32	Pandorina, Cenedesmus	68	Rotifers, Diaptomus
December	1060	36	Cosmarium, Anabaena	64	Keratella, Cladocerans
January	930	10	Pandorina, Closterium	90	Cladocerans, Copepods
February	1268	72	Volvox, Anabaena	28	Cyclops, Nauplii
March	1246	76	Volvox, Oscillatoria	24	Keratella, Brachionus
April	1214	80	Microcystis, Volvox	20	Diaptomus, Cladocerans
May	1428	86	Microcystis, Volvox	14	Copepods, Keratella
Average	1111				
Increase over control (%)	48.0				

$\gamma = 10^{-6}$ g

TABLE II (c) (Contd.)

Plankton concentrations in treated and untreated ponds

20 Kg P_2O_5 + 1 Kg Mn per hectare					
PLANKTON					
Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
June	844	40	Pandorina, Cladophora	60	Difflugia, Copepods
July	1220	62	Scenedesmus, Mycrocystis	38	Rotifers, Copepods
August	1240	60	Microcystis, Volvox	40	Rotifers, Copepods
September	1024	52	Volvox, Cosmarium	48	Copepods, Cladocerans
October	1086	40	Cosmarium, Anabaena	60	Keratella, Cladocerans
November	1114	36	Oscillatoria, Closterium	64	Cladocerans, Rotifers
December	1260	42	Closterium, Scenedesmus	58	Keratella, Brachionus
January	1296	56	Oscillatoria, Scenedesmus	44	Diaptomus, Rotifers
February	1374	68	Anabaena, Volvox	32	Rotifers, Brachionus
March	1496	70	Volvox, Oscillatoria	30	Cladocerans, Copepods
April	1624	86	Microcystis, Oscillatoria	14	Brachionus, Nauplii
May	1824	92	Microcystis, Volvox	8	Diaptomus, Keratella
Average	1267				
Increase over control (%)	69.0				
Increase over phosphate treatment (%)	14.4				

$\gamma = 10^{-6}$ g

TABLE III (a)

Water quality of treated and untreated ponds[1]

Control (No treatment)

Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
June	8.0	85	0.09	0.018
July	7.8	87	0.045	0.027
August	7.1	76	0.036	0.012
September	7.1	68	0.016	0.008
October	7.0	54	0.020	0.003
November	7.3	58	0.024	0.002
December	7.4	70	0.022	0.002
January	7.5	80	0.037	0.001
February	7.5	80	0.050	0.001
March	7.6	94	0.070	0.010
April	7.8	98	0.060	0.055
May	8.0	96	0.065	0.049
Average	7.5	79	0.040	0.016

20 Kg P_2O_5 per hectare

Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
June	8.2	107	0.080	0.018
July	8.0	102	0.270	0.022
August	7.1	83	0.120	0.011
September	7.1	76	0.068	0.008
October	7.1	65	0.045	0.005
November	7.6	70	0.025	0.002
December	7.6	75	0.020	0.004
January	7.5	75	0.025	0.003
February	7.5	72	0.040	0.001
March	7.9	110	0.090	
April	7.9	125	0.085	0.082
May	7.8	128	0.080	0.080
Average	7.6	91	0.079	0.022

1 Kg Mn
20 Kg P_2O_5 + 1 Kg Cu per hectare
1 Kg Fe

Month	pH	Alkalinity ($CaCO_3$)	Phosphate (P_2O_5)	Manganese (Mn)
June	8.1	109	0.100	0.022
July	7.8	103	0.220	0.037
August	7.2	80	0.080	0.018
September	7.2	72	0.032	0.009
October	7.0	54	0.025	0.006
November	7.3	69	0.025	0.005
December	7.6	72	0.030	0.003
January	7.8	80	0.040	0.003
February	7.8	85	0.060	0.001
March	8.0	105	0.080	0.028
April	8.3	124	0.095	0.120
May	8.2	123	0.095	0.110
Average	7.7	90	0.076	0.030

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[1] Expressed in mg/litre

TABLE III (b)

Soil condition in treated and untreated ponds[1]

Control (No treatment)

Month	pH	N		P_2O_5		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.2	740	450	630	38	670	3.5
July	6.5	700	390	650	35	620	4.4
December	6.5	680	370	635	30	650	4.0
May	6.2	730	410	640	35	630	4.0
Average	6.4	713	405	639	35	642	4.2

20 Kg P_2O_5 per hectare

	pH	N		P_2O_5		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.2	810	450	680	35	630	3.6
July	6.6	830	370	680	45	660	4.6
December	6.6	780	320	670	30	680	4.4
May	6.3	810	390	670	38	630	5.3
Average	6.4	808	383	675	37	647	4.1

1 Kg Mn
20 Kg P_2O_5 + 1 Kg Cn per hectare
1 Kg Fe

	pH	N		P_2O_5		Mn	
		Total	Available	Total	Available	Total	Water Soluble
June	6.2	870	470	610	35	630	3.4
July	6.5	800	380	620	45	640	4.8
December	6.6	770	340	610	34	660	4.6
May		830	450	615	39	620	5.4
Average	6.4	818	410	614	38	637	4.5

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[1] Expressed in ppm, except pH

TABLE III (c)

Plankton concentrations in treated and untreated ponds

Control (No treatment)

PLANKTON

Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
June	1267	32	Scenedesmus, Cladophora	68	Copepods, Nauplii
July	1290	60	Oscillatoria, Pandorina	40	Cladocerans, Keratella
August	778	22	Anabaena, Pandorina	78	Copepods, Cladocerans
September	556	12	Oscillatoria, Scenedesmus	88	Copepods, Cladocerans
October	822	66	Oscillatoria, Scenedesmus	34	Brachionus, Keratella
November	778	70	Volvox, Anabaena	30	Keratella, Nauplii
December	444	50	Dictyosphaerium, Volvox	50	Rotifers, Diaptomus
January	822	58	Volvox, Anabaena	42	Cladocerans, Keratella
February	737	42	Pandorina, Oscillatoria	56	Rotifers, Brachionus
March	778	68	Anabaena, Volvox	32	Cladocerans, Cyclops
April	1000	78	Volvox, Anabaena	22	Rotifers, Cyclops
May	1290	82	Microcystis, Anabaena	18	Brachionus, Difflugia
Average	844				
Increase over control (%)	-				

20 Kg P_2O_5 per hectare

PLANKTON

Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
June	1334	42	Ulothrix, Anabaena	58	Copepods, Cladocerans
July	1467	42	Anabaena, Spirogyra	58	Rotifers, Copepods
August	892	18	Anabaena, Spirogyra	82	Rotifers, Cladocerans
September	637	5	Pandorina, Ulothrix	95	Copepods, Rotifers
October	1334	78	Volvox, Oscillatoria	22	Diaptomus, Conochilus
November	1334	60	Volvox, Oscillatoria	40	Rotifers, Brachionus
December	637	42	Cosmarium, Anabaena	58	Cyclops, Keratella
January	1067	62	Closterium, Cosmarium	38	Cyclops, Nauplii
February	955	38	Volvox, Oscillatoria	62	Diaptomus, Cladocerans
March	1334	72	Oscillatoria, Anabaena	28	Keratella, Brachionus
April	1604	72	Volvox, Anabaena	28	Cyclops, Nauplii
May	1890	88	Microcystis, Volvox	12	Keratella, Nauplii
Average	1140				
Increase over control (%)	35.0				

$\gamma = 10^{-6}$ g

TABLE III (c) (Contd.)

Plankton concentrations in treated and untreated ponds

$20\ \text{Kg}\ P_2O_5 + \left.\begin{matrix}1\ \text{Kg Mn}\\ 1\ \text{Kg Cu}\\ 1\ \text{Kg Fe}\end{matrix}\right)$ per hectare

PLANKTON

Month	Total weight γ/litre	%	Predominant phyto-plankters	%	Predominant zoo-plankters
June	1110	50	Oscillatoria, Dictyosphaerium	50	Copepods, Nauplii
July	1667	52	Lyngbia, Oscillatoria	48	Diaptomus, Cladocerans
August	1222	32	Oscillatoria, Cosmarium	68	Copepods, Cladocerans
September	892	10	Pandorina, Lyngbia	90	Rotifers, Cladocerans
October	1344	58	Volvox, Pandorina	42	Rotifers, Nauplii
November	1322	60	Cladophora, Cosmarium	40	Diaptomus, Nauplii
December	778	42	Pandorina, Cladophora	58	Copepods, Cladocerans
January	1322	68	Oscillatoria, Anabaena	32	Keratella, Difflugia
February	778	20	Scenedesmus, Closterium	80	Rotifers, Copepods
March	1512	86	Volvox, Anabaena	14	Difflugia, Arcella
April	1922	78	Microcystis, Volvox	22	Cladocerans, Keratella
May	2222	92	Microcystis, Volvox	8	Rotifers, Cyclops
Average	1367				
Increase over control (%)	62.0				
Increase over phosphate treatment (%)	19.9				

$\gamma = 10^{-6}g$

superphosphate + manganese sulphate treatment was always higher than that for the untreated or superphosphate treated sets. This experiment was initiated in the winter month of December and the increase of plankton concentration in the treated cisterns over untreated ones became more pronounced during the summer months of March-May. The average plankton concentrations for the three sets were 1921,2203 and 2517 /litre showing an increase of 14.6 percent and 31.0 percent respectively for superphosphate alone and superphosphate + manganese sulphate. Thus it is seen that the effect of adding 1 Kg/ha of Mn compares well with that of adding 20 Kg/ha of P_2O_5. It has, however, to be remembered that the soil under investigation was fairly rich in total and available phosphorus (Table I(b)) and was not expected to show a marked response to single phosphatic fertilizer.

The second series of experiments was conducted under complete field conditions in ponds in a fish farm. Here also it was noticed that ponds treated with both superphosphate alone and with superphosphate + manganese sulphate showed higher plankton production than untreated ones, production in the latter case being more than in the former. Fluctuations in plankton concentration in ponds were also irregular under the field conditions; the plankton concentration curves, however, did not show any sharp rise and fall as in the case of cistern experiments (Fig.2). This experiment was continued for one complete year, June-May, so that the plankton concentration and water quality of treated and untreated ponds could be studied for all seasons. It will be seen from Fig.1(b) that in the month of July, one month after treatment, plankton concentrations in both superphosphate treated ponds and in ponds treated with superphosphate + manganese sulphate showed a marked increase over that in untreated ponds, the increase in ponds treated with superphosphate + manganese sulphate being much higher. The difference between the latter two sets was less pronounced in August and during September; October and November the plankton concentration curves overlapped each other, showing no significant difference between the two treatments. From December, however, this difference again became very pronounced and continued until the end of the experiment in May, with an exception in the month of February which is difficult to explain. It was noticed that during summer months of March to May the effect due to manganese as well as phosphate treatments became more marked. It is likely that added nutrients lost from the water phase and bound in the soil by physical or chemical processes, were released during summer months under higher temperature by the increased rate of reduction processes in the soil. During this period the proportion of phyto-plankton in all the ponds was higher ranging from 60 to 92 percent with green and blue green forms like Anabaena, Oscillatoria, Volvox and Microcystis predominating. The added manganese has possibly been utilized for the auto-trophic growth of phyto-plankton with an enhanced rate of carbohydrate synthesis during long periods of sunlight and high temperature, the prevailing initial concentration being sufficient for heterotrophic growth. Though thick dispersions of plankton were noticed at times in some ponds, in no case was there a heavy bloom as observed by Henderson (1949). The average plankton concentrations for the three sets: (1) control, (2) treated with superphosphate and (3) treated with superphosphate + manganese sulphate, were 784,1111 and 1267/ litre respectively, showing an increase of 48 percent and 69 percent respectively for the two treatments. Compared to low manganese Jobra soil here we find an additional increase of 21 percent due to manganese as against 48 percent due to phosphate. Chaudwar soil, however, being deficient in phosphorus showed a marked response (48 percent increase in plankton) to phosphatic fertilizers and comparatively less to manganese. Considering the effect of manganese alone, we find, however, an increase of 14.2 percent for manganese deficient Jobra soil and 14.4 percent for Chaudwar soil with relatively high manganese status. It may therefore be concluded that for pond soils having water soluble manganese ranging from 0.25 to 2.8 ppm and pond water having manganese concentration 0.001 to 0.02 ppm, the addition of this element is efficient and economical to increase the production of plankton in fish ponds. The degree of response to manganese treatment is independent of the manganese status of soil and water in this range.

In the third series of experiments conducted under field conditions with similar procedures as in the previous one, two other common micro-nutrient elements (iron and copper) were incorporated along with manganese. Both these elements are known to take part in metabolic reactions in plants and animals and their role as micro-nutrients for planktonic algae has been studied by many workers (Marsh et al., 1963; Hopkins, 1930a, b and c; 1933; Sommer, 1931). These two elements behave like manganese in their chemical reactions in aquatic environment. Iron is practically insoluble in ionic form at the pH values and oxygen concentrations generally encountered in fresh-water fish ponds. It remains partly as ferric hydroxide either in suspension or adsorbed on colloidal clay miscels and partly as a soluble or colloidal iron-organic complex which appears to be quite stable. The experimental evidence obtained by Harvey (1937) showed that both these forms are assimilable by diatoms and other phyto-plankton organisms. Rodhe (1948) has shown that only a small fraction (about 10 percent) of this iron is available to iron-starved cells of Scenedesmus sp. In the ponds under study the concentration of iron in water ranged from 0.4 to 0.9 ppm as compared to copper and manganese concentrations which ranged from 0.008 to 0.017 ppm and 0.01 to 0.04 ppm, respectively showing an Fe:Mn ratio of 40-23:1. The element copper, though a micro-nutrient, is used for control of algal blooms which sometimes become a nuisance in fish ponds. In alkaline waters only an insignificant fraction of added copper remains in ionic form because of its reaction with carbonate in water, producing basic copper carbonate (Banerjea & Mitra, 1954). A minor fraction may remain as colloidal hydroze. Certain species of Coelastrum and Navicula may be sensitive to copper ion in concentrations of the order of 0.03 ppm, while Anabaena, Aphanizomenon, Tabellaria and Synura can tolerate about 0.05 ppm (Hale, 1922). Pillai (1954) while working with blue-green algae found that an amount of copper inhibiting Phormidium tenue stimulated Spirulina and Oscillatoria sp. It is also often noticed that after an algal population has been destroyed by copper sulphate treatment a secondary maximum of total phyto-plankton of transient nature often develops, possibly due to the nutrient effect of copper or due to nutrients released from decomposed algae. The copper concentrations in the ponds under study range from 0.008 to 0.017 ppm and is thus fairly below the toxic concentration for plankton. The effective concentration of copper and iron on volume basis added in this experiment was 0.01 ppm. As observed in the previous experiment, one month after treatment in July, plankton concentration showed an increase both for phosphate treated ponds and ponds treated with phosphate + manganese sulphate, the increase in the latter case being more than that in the former. This continued up to September, but during October-November the two curves of plankton concentration overlapped, showing that the effect of trace elements is minimal in this period. Later on, however, in the plankton curve for 'phosphate + trace element' an exception was noted in February when plankton concentration in 'phosphate + trace element' treated ponds was markedly lower than that in the other. A somewhat similar variation was noticed in February in the previous experiment, though not to the same extent. During the summer months of March, April and May, the curves showed a trend of regular rise, the effect of phosphate as well as trace elements being more marked.

Comparing the average weight of plankton for the whole period for the three sets of experiments it will be seen that while phosphate alone raised the plankton concentration by 35 percent, there was an additional increase of 27 percent by the combined effect of the three trace elements. However, calculating the effect of trace elements (Mn + Cu + Fe) only an increase of 19.9 percent was recorded in the phosphate treated ponds as against 14.4 percent in ponds treated with manganese alone in the previous experiment, which means an increase of 5.5 percent only due to copper + iron. Thus the copper and iron status of soil and water does not appear to present a deficient condition to the extent of showing a marked response when treated with these elements.

It is interesting to note that during summer months of March, April and May in all the three series of experiments the plankton concentrations showed a trend of regular increase for treated and untreated ponds. At the same time the effect of trace elements and phosphate also became more pronounced as exhibited by difference in plankton weight. Increased proportion of phyto-plankton, particularly green and blue-green forms associated with longer period of sunlight, higher temperature and release of more nutrients under reduced condition in bottom soil and increased bacterial activity, may be responsible for the enhanced rate of auto-trophic synthesis of carbohydrate in summer. From the tables showing chemical quality of water it will be seen that total alkalinity and dissolved nutrients are generally in higher concentrations in summer than in any other season.

4 SUMMARY

To explore the possibility of using trace elements like manganese, copper and iron for increased production of plankton in fish ponds series of experiments were conducted in cement cisterns under semi-field conditions and in ponds under purely field conditions. Two soil types were used in this investigation, one a slightly acidic soil high in phosphorus but low in manganese and the other also with a slightly acidic reaction but low in phosphorus and relatively high in manganese status. The former was treated with only manganese and the latter with manganese alone and in combination with copper and iron. The results showed that both the soils responded fairly to treatment with manganese, showing an increase of plankton weight by about 14 percent due to manganese alone. In the case of high phosphorus and low manganese soil the additional increase of plankton for a dose of 1 Kg/ha of Mn was 16.4 percent which compared well with an increase of 14.6 percent by 20 Kg/ha of P_2O_5, showing that for this type of soil, manganese can be used efficiently and economically as a fertilizer element. In the other soil with low phosphorus and high manganese, the additional increase in plankton weight due to manganese at the rate of 1 Kg/ha was 21 percent against 48 percent by phosphate alone at the rate of 20 Kg/ha of P_2O_5, but when the effect of phosphate + manganese was compared with that of phosphate-manganese it was observed that both the soil types exhibited about 14 percent increase in plankton weight due to manganese alone showing that for the range of water soluble manganese in soil from 0.25 to 2.8 ppm and soluble manganese in water from 0.001 to 0.02 ppm the degree of response was independent of manganese status of soil and water. The effect of incorporating two other trace elements, copper and iron at the same dose for the latter soil did not result in any marked increase in production of plankton.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

Arnon, D.I., 1958 The role of micronutrients in plant nutrition with special reference to photo-synthesis and nitrogen assimilation. Proc.Conf.Ohio,agric.Exp.Sta., (1957):1-33

Banerjea, S and E. Mitra, 1954 Preliminary observations on the use of copper sulphate to control submerged aquatic weeds in alkaline waters. Indian J.Fish., 1(1&2):204-16

Brown, T.E., H.C. Eyster and H.A. Tanner, 1958 Physiological effects of manganese deficiency Proc.Conf.Ohio.agric.Exp.Sta., (1957):135-56

Clark, N.A., 1933 Manganese and the growth of *Lemna*. Plant Physiol., 8:157-61

Clark, N.A. and C.L. Fly, 1930 The role of manganese in the nutrition of *Lemna*. Plant Physiol., 5:24-248

Eyster, H.C., T.E. Brown and H.A. Tanner, 1958 Mineral requirements of *Chlorella pyrenoidosa* under autotrophic and heterotrophic conditions. Proc.Conf.Ohio.agric.Exp.Sta., (1957):157-74

Hale, F.E., Tastes and odours in New York water supply. J.Amer.Water Wks.Ass.,
1922 9:829-37

Harvey, H.W., The supply of iron to diatoms. J.mar.biol.Ass.U.K., 22:205-19
1937

____________, Manganese and the growth of phytoplankton. J.mar.biol.Ass.U.K., 25:
1947 562-79

Henderson, C., Manganese for increased production of water bloom algae in ponds.
1949 Progr.Fish.Cult., 11:157-9

Hopkins, E.F.,, Iron ion concentration in relation to growth and other biological processes.
1930a Bot.Gaz., 89:209-40

____________, Manganese as an essential element for green algae. Amer.J.Bot., 17:1047
1930b

____________, The necessity and function of manganese in the growth of Chlorella sp.
1930c Science, 72:609-10

____________, The effect of small amounts of copper on the growth of Chlorella and
1933 Lemna. Amer.J.Bot., 29:681

Marsh, H.V., H.J. Evans and G. Matrone, Investigations on the role of iron in chlorophyll metabolism. Pl.Physiol., 38-632-64
1963

Mc Hargue, J., The role of manganese in plants. J.Amer.chem.Soc., 44:1592-8
1922

Mehring, H., Die Fisch Teichdüngung. Fish pond manuring. Dtsch.landw.Pr., 45:293
1918

Mortimer, C.H. and C.F. Hickling, Fertilizers in fish ponds. Fish.Publ.,Lond., (5):
1954 155 p.

Patnaik, S., Role of micronutrients on the growth and metabolism of rice plants. Bull.
1955 nat.Inst.Sci.India, 8:65-8

Pillai, V.K., Some factors controlling algal production in soil water lagoons. Proc.
1954 Indo-Pacif.Fish.Coun., 5:78-81

Pirson, A., Manganese and its role in photosynthesis. Proc.Conf.Ohio.agric.Exp.Sta.,
1958 (1957):81-98

Rodhe, W., Environmental requirements of fresh-water plankton algae. Symb.bot.upsaliens., 10:149
1948

Saegar, A., Manganese and the growth of Lemnaceae. Amer.J.Bot., 20:234-45
1933

Sommer, A.L., Copper as an essential element for plant growth. Pl.Physiol., 6:339-45
1931

Swingle, H.S., Experiments on pond fertilization. Bull.Ala.agric.Exp;Sta., (264)
1947

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THE ROLE OF SOILS IN FISH PRODUCTION IN PONDS

by

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Abstract

The paper is based on the results of investigations carried out by different scientists in ponds in Poland and deals with the role of river drainage basins in the formation of pond soils and with the influence of the soils in the drainage basins on the chemical composition of the water irrigating the ponds. It is characteristic of the metabolism in ponds that the synthesis of organic matter outbalances its decomposition and consequently organic matter accumulates on the bottom of ponds. The dependence of the migration of important macroelements on the synthesis and decomposition of organic matter, as well as the influence of the decomposition of organic matter on the oxygen conditions in pond water, are emphasized.

Treatments of ponds, aimed at the mobilization of nutrients accumulated in pond soils and at the counteraction of "ageing" are discussed.

The author suggests some special lines of investigation on pond environment and stresses the importance of simultaneous investigations of soils and water in ponds and the synthesis and decomposition of organic matter.

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ROLE DES SOLS DANS LA PRODUCTION PISCICOLE DES ETANGS

Résumé

Cette communication, faisant état des travaux effectués en Pologne par divers chercheurs, traite du rôle des bassins versants dans la formation des sols des étangs ainsi que de l'influence du sol des bassins versants sur la composition chimique de l'eau alimentant les étangs. Il est caractéristique du métabolisme des étangs que la synthèse des matières organiques l'emporte sur la décomposition de ces matières de sorte que celles-ci s'accumulent sur le fond. L'auteur souligne les rapports étroits entre la migration d'importants macroéléments et la synthèse et la décomposition des matières organiques ainsi que l'influence de la décomposition de ces matières sur le teneur en oxygène de l'eau.

Un autre problème examiné est celui des traitements appropriés pour mobiliser les éléments nutritifs accumulés dans le sol des étangs et empêcher le "vieillissement".

L'auteur suggère quelques aspects particuliers du milieu aquatique qui méritent d'être étudiés plus à fond et souligne l'importance qu'il y a à mener de front des recherches sur les sols et les eaux des étangs et la synthèse et la décomposition de la matière organique.

LA FUNCION DE LOS SUELOS EN LA PRODUCCION PISCICOLA EN ESTANQUES

Extracto

Este trabajo se basa en los resultados de las investigaciones llevadas a cabo por diferentes hombres de ciencia en estanques de Polonia y trata de la función de las cuencas de desagüe de los ríos en la formación de suelos de estanques, así como de la influencia de las cuencas de desagüe sobre la composición química del agua que los baña. Es característico del metabolismo en los estanques que la síntesis de la materia orgánica supera a su descomposición y que, por consiguiente, la materia orgánica se acumula en el fondo de los mismos. Se hace resaltar la importancia de la migración de importantes macroelementos sobre la síntesis y descomposición de materia orgánica así como la influencia de la descomposición de esta última en la oxigenación del agua del estanque.

Se examinan los tratamientos de estanques destinados a la movilización de los elementos nutrientes acumulados en sur suelos y a contrarrestar los efectos de su envejecimiento.

El autor sugiere algunas líneas especiales de investigación sobre el medio ambiente de los estanques, y pone de relieve la importancia de la investigación simultánea de suelos y agua y la síntesis y descomposición de la materia orgánica.

1 INTRODUCTION

Pond soils are the source of various organic and mineral compounds which penetrate into the water after biochemical and chemical changes. This interchange between pond soils and water, supplies the aquatic plants with mineral nutrients. The pond soil is also the habitat of the bottom fauna, which is an important source of food for fishes cultured in ponds. The soils contain plant spores and seeds, eggs of aquatic animals, as well as parasites, bacteria and viruses responsible for diseases in fish. Pond soils, therefore, play several important roles in the production cycles of fish ponds.

2 THE ROLE OF DRAINAGE BASINS IN THE FORMATION OF POND SOILS

Pond soils are formed under very specific conditions, different from those in which land soils or the bottom deposits in lakes are formed. This specifity depends mainly on the periodical flooding of ponds, and in higher altitudes ponds remain drained for longer periods than in the lower. The water supply to the ponds brings in suspensions and dissolved salts eroded and washed away from the whole of the drainage basin. In the ponds, in altered physico-chemical conditions, the suspensions and salts are subject to sedimentation and precipitation. The mineral suspensions carried into ponds are chiefly colloidal fractions and for that reason the geomorphology and the soil cover of the drainage basin, from which the ponds are irrigated, as well as the quantity and the distribution of rainfall have a great influence on the mechanical composition of the mineral matter. The chemical composition of the water supply to ponds also depends upon the geological structure of the drainage basin and the fertility of its soils. However, this concerns clean waters only, as the chemical composition of surface waters becomes more and more affected by sewage and industrial wastes.

It is a common belief that the productivity of ponds situated on rich soils is much higher than of others. The influence of the drainage basins on fish production may be illustrated by a comparison between the Polish ponds situated in the southern highland (Little Poland) and those irrigated from the Carpathian rivers. In the former region where carbonate rocks and loess soils as well as rendzinas prevail, fish yields are double or triple those in the sub-Carpathian region, where the drainage basins are formed of Flysh rocks covered with soils poor in nutrients (Pasternak, 1959; 1965; Wróbel, 1965).

In moderate climatic conditions the productivity is higher in ponds located on carbonate soils or irrigated from rivers whose drainage basins are built of carbonate rocks, as the soils formed on these rocks are usually richer, and moreover the content of calcium carbonate in the water supply is higher. Calcium carbonates in pond water, because of their buffer capacity, exert a favourable influence as they diminish the amplitudes of pH fluctuations in water, and also they are bearers of an important nutrient, carbon dioxide. It is especially important in zones of moderate climate, where the synthesis of organic matter outbalances its decomposition in water reservoirs. In subtropical and tropical climates the carbonates play a smaller role as bearers of carbon dioxide, as the turn-over rate of metabolism is higher and gives a constant supply of this compound.

The soil on which the ponds have been built, exerts a favourable influence on the productivity of the ponds only for a few years of utilization for fishery purpose (Starmach, 1956). As time goes on, a proper pond soil is formed on the primary soils as a result of constant sedimentation of suspensions and their mixing with organic matter produced in the ponds themselves and with precipitated mineral compounds (carbonates, phosphates, ferric hydroxides). Although it would seem probable that in ponds irrigated from the same river these soils ought to be similar, nevertheless in neighbouring ponds the chemical properties of the soils are often different, because of different systems of irrigation, of different areas and depths, as well as of the ratio of the volume of the water in the pond to the volume of the inflow.

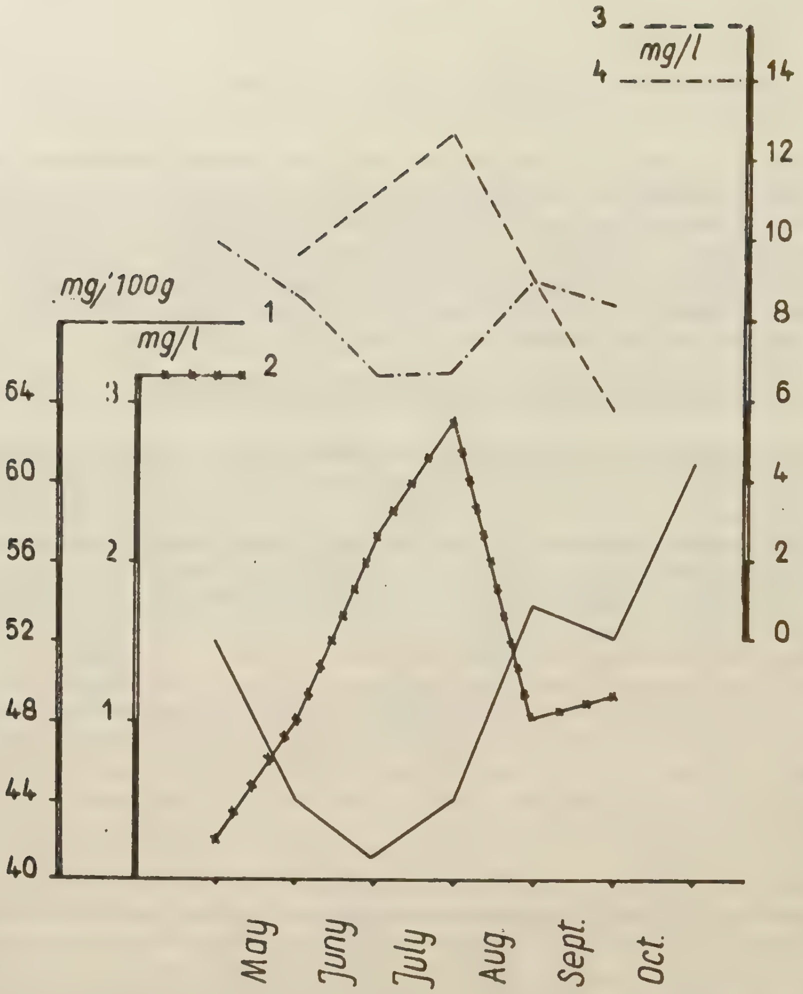

Fig. 1 Iron content in the bottom (1) and in the water (2), CO_2 content (3) and O_2 content in the water in pond (after Wróbel, 1960)

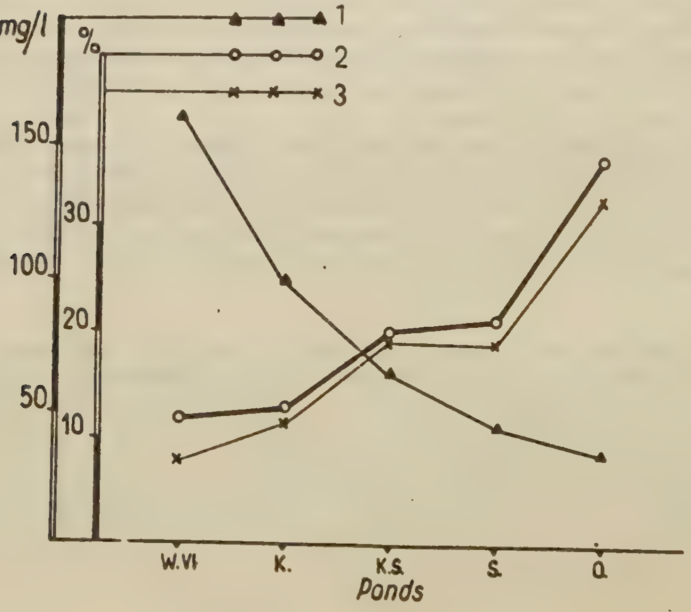

Fig. 2 The dependence of electrolyte content of water on clay minerals in pond soils, 1 - electrolyte content, 2 - clay minerals, 3 - content of salts in soils (after Pasternak, 1958)

3 THE INTERDEPENDENCE OF SOIL AND WATER IN PONDS

In such shallow water bodies as ponds there is an intense interchange of organic and mineral compounds between the soil and the water. The soil profits more as it is constantly enriched in organic matter, phosphates and carbonates (Stangenberg, 1943); in the latter only when the inflowing water is rich in carbonates.

The main processes taking place on the bottom of the ponds are accumulation and decomposition of organic matter. As a result of the accumulation of organic matter important macro-elements are eliminated from the pond water and immobilized on the bottom, while the decomposition of organic matter not only releases mineral compounds but contributes also to the dissolution of unavailable phosphates and carbonates (influence of carbon dioxide).

Phosphorus is one of the elements easily subject to retrogradation in an acid medium as well as in a basic one. The retrogradation of phosphorus and the accumulation of insoluble ferric or calcium phosphates in soils causes a rapid decrease of PO_4 supplied by fertilization. Fish exert an important influence upon the rapidity of this process by mixing water with the loosened top layer of pond soil (Hepher, 1958), although the stirring up of the bottom may also be favourable to the transfer of bottom phosphates into the water. In view of the rapidity of the chemical or physico-chemical fixation of phosphates in pond soils Stangenberg (1942) divides the vegetation season into two subperiods: (i) when the phosphates are rapidly fixed by the bottom, and (ii) the period of production proper, when they are slowly released because of a more rapid mineralization of the organic matter at higher temperature levels in the water and because of a change in oxidation-reduction potential. Pond soils are rich in nitrogen stored in organic matter; however, this is not available to aquatic plants. Its total content can therefore not be taken as an index of the fertility of the pond (Stangenberg, 1943; 1949). The role of bacteria found in pond soils in the fixation of elementary nitrogen has not yet been fully explained. The favourable effects of nitrogen fertilization on ponds (Wróbel 1962; Vinberg and Liakhnovich, 1965) and the immediate results of investigation on Azotobacter (Matusiak and Rawski, 1956) seem to prove that the role of bacteria in moderate climates is not equivalent to that of subtropic and tropic blue-green algae in free nitrogen fixation.

The role of pond soils if fertilized with nitrogen manures, may be regarded as rather negative, as the ammonium form of nitrogen may be absorbed by soil colloids and the nitrate form in the contact layer may be subject to denitrification. Liberation of the ammonium form occurs only in a medium reduced by the decomposition of organic and mineral colloids (Mortimer, 1941; 1942), and this process depends again on the quantity of organic matter and on the rapidity of its decomposition. Ammonia is also liberated by the mineralization of organic matter in the bottom of the ponds.

The exchange of potassium between soil and water is relatively less dependent on the carbon turn-over cycle; insoluble potassium salts also do not form in ponds. A high hydration of soil colloids is favourable to the passing of potassium from soil to water and for that reason there is never a total lack of this nutrient in ponds. Only in ponds located on peat bogs, or in those overgrown by submerged vegetation may the potassium content fall below 0.5 mg/l.

The presence of iron, on the contrary, depends largely on the content of free carbon dioxide, as shown by the author's investigations in the ponds of the Laboratory of Water Biology of the Polish Academy of Sciences (Wróbel 1960), (Fig. 1).

The conditions of exchange of various ions between soil and water are not so simple as they appear from the above, as their passing from soil to water is mainly dependent on the content of clay minerals. Pasternak's investigation (1958) proved that the passing of electrolytes is still more dependent on the colloid content in soil than on its fertility (Fig. 2). Even if the top layer of pond soil is rich in colloids, this does not prevent some elements from being washed out. Lyzimetric investigation of ponds (Wróbel, 1959) proved that calcium is the most easily washed out factor. The great lability of

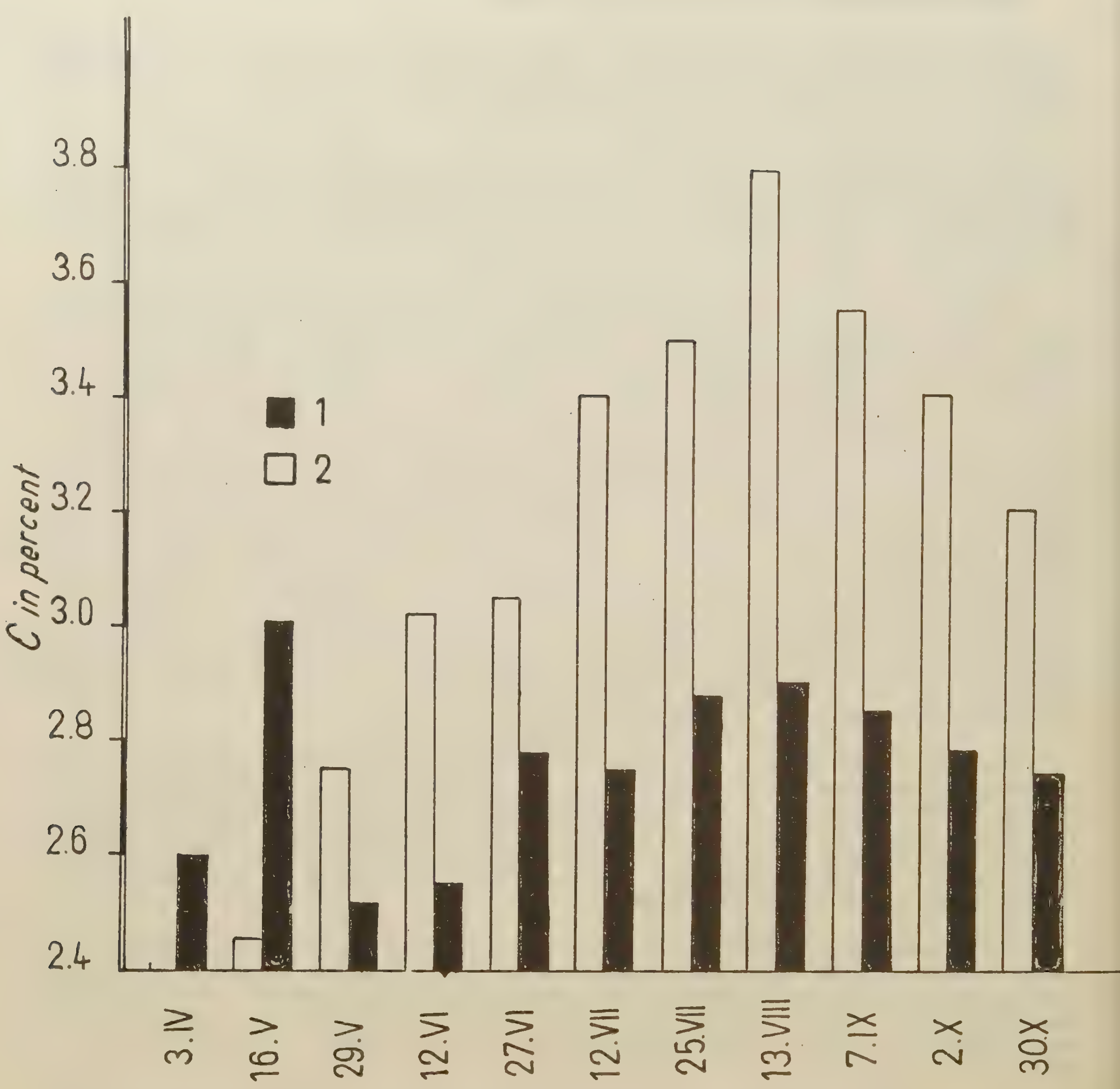

Fig. 3 Seasonal changes in organic carbon in pond soils, 1 - control pond, 2 - fertilized pond (after Wróbel, 1965)

calcium explains the lack of visible effects of liming ponds on the physico-chemical conditions of pond soils.

The decomposition of organic matter in the bottom greatly affects the oxygen conditions in the water in intensely cultivated ponds (pond fertilization, fish feeding). The oxygen conditions in pond water depend on two factors: on the intensity of photosynthesis and on the consumption of oxygen by decomposition of organic matter. The ratio of oxygen production to its consumption is not similar in various months of the growing season. In the lower temperatures of the first months of the season (in moderate climates in May and June) this ratio amounts in fertilized ponds to three or four, i.e. about 25 to 30 percent of the organic matter produced is subject to decomposition in the water and the rest of it accumulates on the bottom. Fig. 3 shows the course of accumulation of organic matter in a fertilized and a control pond.

With the increase of water temperature the ratio of oxygen production in water to its consumption decreases, and in August becomes about one. In this warmest month the rate of decomposition of matter in the bottom increases. Because of a strong oxygen stratification during the day (Fig. 4) organic matter decomposes in anaerobic conditions, and the products of an incomplete oxidation pass into the pond water making the unfavourable oxygen conditions still worse. These conditions are especially dangerous in shallow, strongly eutrophic ponds. In these ponds, as well as in the deep ones, the ratio of the quantity of produced organic matter to the unit of area is almost identical because of the limited penetration of light into the deep layers of water, but on the other hand in shallow ponds smaller quantities of organic matter decompose, because the dead algae cells do not have so far to sink and the degree of overgrowth by submerged vegetation is greater. In these ponds the accumulation of organic matter on the bottom is therefore higher, the ratio of oxygen content to the unit of area smaller, and the amplitude of oxygen content fluctuations in the 24 hours cycle higher. To counteract the unfavourable influence exerted by the bottom on the oxygen conditions in water, it is necessary either to remove surplus organic matter by increasing the flow of water in ponds during the growing season, or, when the volume of the fresh water inflow is limited, to submit only deep ponds to intense cultivation. These great fluctuations of oxygen content in water may probably account for the prevalence of branchiomycosis, a dangerous fish disease occuring as a rule in intensively cultivated shallow ponds in a narrow zone with temperate climate.

The oxygen conditions in pond water ought to be more thoroughly investigated, as these conditions limit the intensification of present rearing methods. As methods of fish feeding improve, the most important treatment of the ponds will not be aimed at increasing the natural food supply, but at assuring optimum oxygen conditions, and thereby allowing maximum exploitation of the provided foods.

4 CULTIVATION OF POND SOILS

Cultivation of fish inevitably leads to the increase of organic matter in pond soils and then to reduction conditions. The concentration of organic and mineral compounds, especially of insoluble phosphates, proves that in the majority of cases the influence of water and the processes occurring in water on pond soils, is stronger than the influence of the pond soils on the water. The cultivation of pond soils aims chiefly at increasing the influence exerted on the water by pond soils, and endeavours to counteract a process known as the "ageing of ponds". In temperate climates the cultivation of pond soils consists mainly in a thorough annual winter draining, sometimes combined with a summer fallowing (agriculture - pisciculture rotation).

The main aims of winter draining of ponds are to supply the pond soil with atmospheric oxygen and to interrupt the reduction processes as well as to increase the rapidity of mineralization of organic matter (Danielewski, 1965; Wróbel, 1958). The mineralization of organic matter increases the content of mineral nitrogen compounds from 34 to 146 kg/ha N (Danielewski, 1965). A further advantage of the winter draining of pond soils is a decrease in acidity; the reaction moves to the basic side and the exchange acidity decreases (Wiesner, 1934).

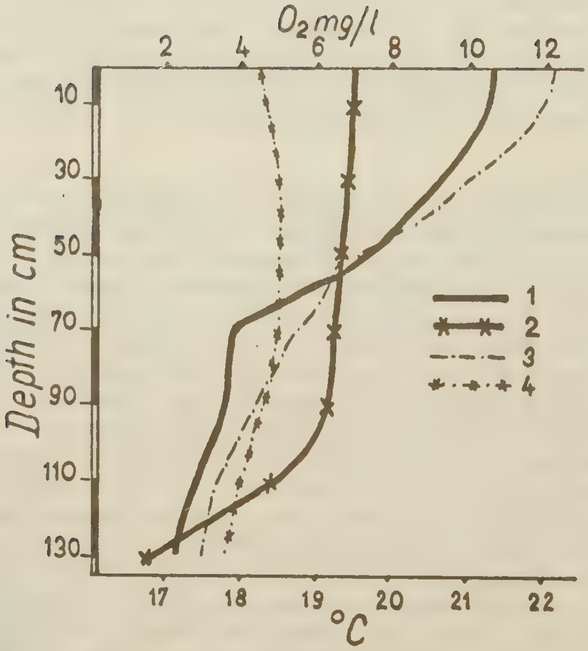

Fig. 4 Temperature and oxygen stratification in the water of a fertilized pond in August 1962. 1- O_2 content in the afternoon, 2 - O_2 content in the morning, 3 - temperature in the afternoon, 4 - temperature in the morning (after Wróbel, 1965)

The winter draining of pond soils is especially advised by ichthyo-pathologists and parasitologists because of its sterilizing action.

The advisability of an annual winter draining is a subject of discussion among hydrobiologists; they are not unanimous in their views, as the draining of ponds affects the biocenotic relations of the pond environment. The rapid formation of plankton plant and animal communities in ponds for fry (in the Dubisch system) proves that neither phyto- nor zooplankton is affected, even in ponds which remain drained for a long period (the ponds used for the youngest fry are flooded for four to six weeks of the year only).

It does not seem necessary to discuss the liming of pond soils, which is a widely employed treatment. Its disinfectant action or its influence on the mobilization of phosphorus content, especially in acid soils, is well known. This treatment is especially important in Poland, as 50 percent of the ponds are located on highly acid soils.

5 MAIN TRENDS IN THE INVESTIGATION OF POND ENVIRONMENT

The actual knowledge of the influence of pond soils on the productivity of ponds is based upon the results of wide but single investigations, or of laboratory research. The former determine, according to Stangenberg (1943), the potential fertility, the latter explain some chemical processes, but neither embrace the biochemical processes in pond water and soils during the entire growing season. Pond soils are an integral part of every pond and participate in every metabolic process, and for this reason investigation of the pond environment ought to include the bottom as well as the water and should continue throughout the whole season.

The calcium, phosphorus, nitrogen, iron and other nutrient cycles are dependent, in a direct or indirect way, mainly on the carbon cycle, so the investigation should embrace the accumulation and decomposition of organic matter in the pond bottom, as well as the primary production of phytoplankton and the oxygen consumption in pond water. It is also of great importance to determine the conditions of the decomposition of organic matter in the bottom. The organic matter accumulation should be investigated by determination of organic carbon, its decomposition by determination of biochemical oxygen demand, and the conditions of decomposition by measuring the redox potential. The role played by humus compounds in ponds also remains so far unexplained, although it seems that their absorption capacity is of great significance in the process of exchange between plant organisms and environment (Badura, 1965). Not till these basic processes are explained, can the cycles of particular macro- and micro- elements be investigated. Investigations on pond soils carried out from this standpoint would not only be important in explaining the chemical changes in different elements, but also in characterizing the pond bottom as the habitat of bottom fauna.

Investigations on metabolism in pond soils should be carried out simultaneously with investigations on water in different climatic zones by the same group of scientists, or at least by uniform methods if by different people.

These investigations should be sponsored by FAO or carried out within the International Biological Programme (IBP). The necessity of increasing the output of fish in ponds necessitates these investigations. Fish rearing is the only branch of animal production based so much on natural processes and for that reason it must be founded on an intimate knowledge of the pond environment.

6 REFERENCES

Badura, L., 1965 On the mechanism of the "stimulating" influence of Na-humate upon the process of alcoholic fermentation and multiplication of yeasts. Acta Soc.Bot.Polon., 34(2):287-328 (in Polish, English summary)

II-VI/E-7

Danielewski, S., Mineralisation of bottom sediments during winter draining of fish
1965 ponds. Roczn.Nauk rol.(B), 2:341-59 (in Polish, English summary)

Hepher, B., On the dynamics of phosphorus added to fishponds in Israel. Limnol.
1958 Oceanogr., 3:84-100

Matusiak, K. and W. Rawski, Investigations on Azotobacter in the experimental
1956 fishponds at Golysz and Ochaby. Biul.Zakl.Biol.Stawów, 4:155-7 (in Polish)

Mortimer, C.H., The exchange of dissolved substances between mud and water in lakes.
1941 J.Ecol., 29:280-329

————————, The exchange of dissolved substances between mud and water in lakes.
1942 J.Ecol., 30:147-201

Pasternak, K., Influence of the pond soil composition on the chemical properties of
1958 water. Biul.Zakl.Biol.Stawów, 7:27-60 (in Polish; German summary)

————————, Soils of the fishponds in the upper basin of the river Vistula. Acta
1959 hydrobiol.,Kraków, 1(3-4):221-83 (in Polish; English summary)

————————, Pond soils formed out of silt loam formations. Acta hydrobiol.,Kraków,
1965 7(1):1-26 (in Polish; English summary)

Stangenberg, M., Die Produktionsbedingungen in den Teichen. 3. Chemische
1942 Zusammensetzung des Oberflächenwassers der mit Superphosphat gedüngten und nicht
gedüngten Karpfenteiche, während der Zuchtsaison. Arch.Hydrobiol.,
32:525-72

————————, Die Produktionsbedingungen in den Teichen. Die chemische Zusammensetzung
1943 der Böden unter den Teichen. Geol.Meere, 6:1-64

————————, Nitrogen and carbon in the bottom deposits and in the soils under carp
1949 ponds. Verh.int.Ver.Limnol., 10:422-7

Starmach, K., The life of freshwater fish. Warszawa, Państwowe Wydawnictwo Rolnicze
1951 i Leśne. 301 p. (in Polish)

————————, Ponds as culture habitat. Culture of pond fishes. Warszawa, Państwowe
1956 Wydawnictwo Rolnicze i Leśne, 13-79 (in Polish)

Strumieński, O., On question of damming, measuring and stocking of ponds and also on
1873 canals, on leveling and water supply. Books necessary for all farmholders.
Printed by Lazarz Andrysowic in Cracov. T. Kucharzewski Ed., published by
Academy of Science in 1897 (in Polish)

Vinberg, G.G. and V.P. Liakhnovich, Fertilization of ponds. Moskva.Izdat.Pishchevaia
1965 Promyshlennost, 249 p. (in Russian)

Wiesner, E.R., Untersuchungen über den Einfluss der winterlichen Trockenlegung der
1934 Teiche auf die chemische Beschaffenheit des Teichschlammes. Arch.Hydrobiol.,
27

Wróbel, S., Attempts at explaining chemical transformations in pond dried in winter.
1958 Biul.Zakl.Biol.Stawów, 6:97-208 (in Polish; German summary)

————————, Introduction to lysimetric investigations on the bottom of ponds. Acta
1959 hydrobiol.,Kraków, 1(2):87-107 (in German; Polish summary)

Wróbel, S., 1960 The interdependence between the bottom and the water in ponds. *Acta hydrobiol., Kraków*, 2(2):69-124 (in Polish; German summary)

____________, 1962 Influence of N- and P- fertilization on chemical composition of water, primary production of phytoplankton, and fish crop in ponds. *Acta hydrobiol.,Kraków*, 4(2):151-204 (in Polish; German summary)

____________, 1965 Causes and consequences of pond eutrophication. *Acta hydrobiol., Kraków*, 7(1):27-52 (in Polish; English summary)

____________, 1965a Chemical composition of the water in ponds in southern Poland. *Acta hydrobiol.,Kraków*, 7(4):303-16 (in Polish; German summary)

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II/E-8

INORGANIC FERTILIZERS FOR POND FISH CULTURE

by

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INORGANIC FERTILIZERS FOR POND FISH CULTURE

Abstract

The first part of the paper attempts to review the fish pond fertilization practices in the Indo-Pacific region. In practically all the countries in the area, pond fertilization is characterized by the heavy use of organic materials that serve either as direct feed for the fish or fertilizer for the pond. That there is a general lack of basic information on the use of inorganic fertilizers in these parts is recognized, but in recent years there have been experiments on their use with demonstrated success.

The second part of the paper explains the experiments on the use of inorganic fertilizers in fresh-water ponds conducted by the author in the Auburn University Farm Ponds Project, Auburn, Alabama, U.S.A. in 1959. The experiments gave the following results:

(i) The amount of plankton and bottom fauna (mainly aquatic insects) was significantly higher in the fertilized than in the unfertilized ponds.

(ii) Using two test fish, common carp and goldfish, the average production in fertilized ponds was found to be higher than in the unfertilized ones.

(iii) Continued application of complete fertilizers to the test ponds for the previous fifteen years showed a residual effect calculated to be 3.7 times more for carp and 1.7 for goldfish.

LES ENGRAIS INORGANIQUES DANS L'ELEVAGE DES POISSONS EN ETANG

Résumé

Dans la première partie de la communication, l'auteur passe en revue les méthodes pratiquées dans la région indo-pacifique en matière de fumure des étangs de pisciculture. Dans presque tous les pays de la région, la fumure se caractérise par un emploi massif de matériaux organiques qui servent soit à alimenter directement le poisson soit à fertiliser l'étang. Il est reconnu que, dans ces régions, on manque en général de renseignements de base sur l'utilisation des engrais inorganiques, mais au cours des récentes années ces matières ont été expérimentées avec un succès probant.

La deuxième partie de la communication décrit les expériences sur l'utilisation d'engrais inorganiques dans des étangs d'eau douce que l'auteur a effectuées en 1959 à Auburn, Alabama (Etats-Unis) dans le cadre de la Auburn University Farm Ponds Project. Ces expériences ont donné les résultats suivants:

(i) La quantité de plancton et de benthofaune (principalement des insectes aquatiques) était considérablement plus élevée dans les étangs fertilisés que dans ceux non fertilisés.

(ii) En utilisant comme témoins deux espèces de poisson, la carpe commune et le poisson rouge, il a été constaté que la production moyenne dans les étangs fertilisés était plus élevée que dans les étangs non fertilisés.

(iii) La fertilisation permanente des étangs d'essais avec des engrais complets pendant les 15 années précédant les expériences ont montré qu'il existe un effet résiduel qui aurait un coefficient de 3,7 pour la carpe et 1,7 pour le poisson rouge.

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FERTILIZANTES INORGANICOS PARA LA PISCICULTURA EN ESTANQUES

Extracto

La primera parte del estudio pasa reseña a los procedimientos de fertilización aplicados en los estanques piscícolas de la región del Indopacífico. En casi todos los países de la zona, prácticamente, la fertilización en estanques se caracteriza por el gran empleo de materias orgánicas que sirven como alimento directo para los peces o como fertilizante para el estanque. Se reconoce que exite una falta general de información básica sobre el empleo de fertilizantes inorgánicos en tal región, pero en estos últimos años se han realizado experimentos sobre su uso que han obtenido un claro éxito.

La segunda parte del estudio explica los experimentos sobre el empleo de fertilizantes inorgánicos en estanques de agua dulce realizados por el autor en 1959 en el proyecto de la Universidad de Auburn, Auburn, Alabama, E.U.S. sobre estanques piscícolas. Los experimentos dieron los resultados siguientes:

(i) La cantidad de planoton y de fauna bentónica (pincipalmente insectos acuáticos) fué mucho mayor en los estanques fertilizados que en los no fertilizados.

(ii) Empleando dos peces de ensayo, la carpa común y la carpa dorada la producción media en los estanques fertilizados fué mayor que en los no fertilizados.

(iii) La aplicación constante de fertilizantes completos en los estanques de ensayo durante los 15 años anteriores, indicaron un efecto residual que se calculó en 3,7 veces más con respecto a la carpa y en 1,7 veces con respecto a la carpa dorada.

This paper endeavors to review the fish pond fertilization practices in countries in the Indo-Pacific region, and to discuss some basic information on the use of inorganic fertilizers obtained from experiments done by the author in Auburn, Alabama, U.S.A.

1 FISH POND FERTILIZATION IN THE INDO-PACIFIC REGION

The efforts directed toward increasing fish production in fish ponds in the Indo-Pacific area have received considerable attention. The addition of fertilizing substances to ponds in order to attain increased production has been extensively practised. Unfortunately, most of the trials have been confined largely to the random application of organic materials that are cheap and easily available. Whatever abounds locally is used and it is often difficult to establish whether these organic matters are fertilizers for the ponds or direct feeds for the fish stock. The kind of fertilizer and the amounts used, as well as methods of application, vary with indigenous experiences and availability of fertilizing products. Only recently have experiments on the use of inorganic fertilizers been undertaken.

1.1 Japan

To derive maximum production from fish ponds, intensive fish culture techniques, including the use of fertilizers and artificial feeds, are employed in Japan. Frequent and heavy feeding of the fish stock is done and undoubtedly the feed serves both as a direct fish food and as a fertilizer. Some of the substances commonly used include silkworm pupae, cereal by-products (rice bran and meddlings and barley), male chicks from poultry farms, cheap marine fish (sardines) and slaughter-house products (horse and pig livers, etc.) prepared for pond application.

Inorganic fertilization of fish ponds was considered in Japan previously as a minor management practice. In the hope of triggering off the growth of the desirable flora, the phytoplankton, one to two applications of ammonium sulphate and superphosphate used to be routinely made. In some instances, pond fertilization with inorganic substances met with disfavour due to their fertilizing effect on obnoxious weeds. This could have been due to minimal application of the mineral fertilizer. In recent years, studies have been conducted on the use of this type of fertilizer in heavier dosages and more frequent application than previously practised. Seven applications instead of one or two per year have been tried with good results. Maximum success has been obtained with combined intensive feeding and inorganic fertilizer application.

1.2 Taiwan

Intensive methods of fish cultivation are practised in the fish ponds of Taiwan. Heavy feeding with various organic materials, indistinguishable from fertilization per se, has long been a standing practice. The more common substances used include: rice and wheat bran, night soil, tea seed, peanut and soybean cake, Leucaena-seed meal and various animal manures. For a long time a pattern of fertilization characterized by four applications of these organic fertilizers during the crop season was followed. Then there grew a great demand for these fertilizing materials, giving rise to unprecedented costs.

From 1953 to 1956 a series of experiments were undertaken to determine the effectiveness of inorganic fertilizers which heretofore had not been generally utilized in fish ponds. These studies include comparison of the efficiency and economy of using organic and inorganic materials applied singly or in combination. The following results were established:

(i) Inorganic fertilizers of 8-9-2 or 8-4-2 (N-P-K) at the rate of 300 to 500 kg/ha/year can be used successfully in milkfish (Chanos chanos) ponds in Taiwan;

(ii) Inorganic fertilizers were found more effective in clear pond water with salinity above 1.5 percent and sufficient sunlight reaching the pond bottom;

(iii) The average production of ponds treated with complete inorganic fertilizer was equal to that produced by treatment with double the amount of rice bran, or with night soil 30 times that of the mineral fertilizer used. Based on current prices in Taiwan at the time the studies were being conducted, the expenses incurred with the use of organic materials exceeded that of the chemical fertilizers.

(iv) Compared with ponds receiving either chemical or organic fertilizers, those receiving combined chemical and organic fertilizers yielded the highest increase in production.

1.3 Southern China and Hong Kong

The use of organic materials, both as feeds and fertilizing substances in ponds, is also an age-long management technique in Southern China and Hong Kong. The materials used include silkworm pupae, cut land grass, soybean meal, goatweed and other strong odoured weeds, pig, sheep, buffalo and cattle manure, night soil, tea seed, poultry droppings, aquatic plants, rice bran and broken rice, and peanut cake. It is not unusual for latrines, and pig and duck pens to be built over the ponds.

There seems to be no standard method of fertilizer application in this area but different local practices have been developed in the different fish producing communities. Different organic fertilizers such as cow dung, green manure, hog manure, etc., are often used in rotation during the growing season. Likewise, fish and plant crops are raised in rotation in the same field. With the continued use of organic fertilizers the pond bottom gradually becomes elevated, necessitating periodic draining of the pond water and drying and scraping of the bottom soil.

It is not known whether or not inorganic fertilizers are used in Southern China and Hong Kong.

1.4 Malaysia and Singapore

All cheap and easily available organic materials are used in ponds to serve the dual purpose of feeding and fertilizing. There are no records showing whether or not inorganic fertilizers are used. However, with the establishment of the Fish Culture Research Institute at Batu Berendam, Malacca, Malaysia, experiments on mineral fertilization of ponds are being undertaken. Recent findings of that Institute on $N-P_2O_5-K_2O$, used separately and in various combinations, show that about 44 kg/ha/year P_2O_5 is the optimum fertilization for ponds in that region. This produced a yield of fish even higher than that produced by ponds fertilized with six and three-quarter tons of cow dung, an indication that inorganic fertilizers can be as cheap, if not cheaper than organic manures for fish pond fertilization.

"Mixed farming" or the integration of animal husbandry, crop raising and fish culture for the maximum utilization of farmland, is a well-developed practice in Malaysia. The unique feature of this scheme is the attempt to circulate within the system the nutrients that have been made available to it from outside, and conserving these nutrients in order to reduce to the minimum the need for external materials. Thus the animal wastes fertilize the water to produce the maximum growth of microscopic plants as well as higher aquatic plants. These are in turn fed on by the fish. Part of the luxuriant growth of higher aquatic plants and excess stock of the rapidly multiplying species of fish are gathered and used to augment the feed used in the animal husbandry unit. In order to maintain their original depth, ponds are periodically drained, dried, and their bottoms scraped. The scrapings have been found to be a good fertilizer for vegetable gardens and orchards.

1.5 India

Heavy use of organic substances and manures as direct feeds and pond fertilizing materials is practised also in India as in other Indo-Pacific countries. The materials commonly used include cow dung, stable refuse, poultry manure, oil cake and cut grass.

With the growth of cities and unprecedented increases in population, the efficient disposal of refuse and sewage has become a big problem. India has demonstrated, particularly in the Bidyadhari Spill area in Calcutta that fish culture in sewage-irrigated areas can provide a cheap means of sewage purification. From the standpoint of sanitation it has been observed that fish, fortunately, cannot survive normally at points in the sewage line where the oxygen content is too low and where pathogens are too heavy to cause danger to public health. On the other hand, where the water has become clean and/or well diluted, the enriched water favours a very rapid growth of the desirable species of fish to marketable size in as brief a period as six to eight months.

1.6 Indonesia

Like all the other countries of the Indo-Pacific region, Indonesia utilizes organic materials and manures for the artificial enrichment of her fish ponds. Pig, duck, and other animal manures are used. Vegetables found in quantities are used as green manuring materials. Experiments using the marigold plant, *Tithonia diversifolia*, for green manuring resulted in increased production of common carp (*Cyprinus carpio*) and tilapia (*Tilapia mossambica*) in ponds.

The use of inorganic fertilizers in this country is in the experimental stage. Its bright prospects seem to be indicated by the surprisingly high production derived from ponds in volcanic areas, the water of which is heavily laden with mineral nutrients.

The brackish-water milkfish ponds get fertilized incidentally due to the management practices generally followed. Periodic replenishing of the pond water with new tidal water brings in nutrients with the water supply. The draining and drying of the pond bottom after each crop period is invariably followed by heavy growth of blue-green algae in the ponds. It has been postulated that nitrogen fixation may be taking place with the growth of this type of algae.

The use of sewage water for fish production purposes has proved to be successful in the cities of Jogjakarta and Bandung. Here fresh sewage is first treated in septic tanks and later allowed to flow and mix with irrigation water to feed fish ponds or rice fields where fish is raised. Production of common carp, tilapia and milkfish is high from these sewage-fed areas.

1.7 Philippines

Pond fish culture in the Philippines is predominantly confined to brackish-water ponds for milkfish; fresh-water fish ponds are still few and limited in extent. During the crop period, the regular replenishment of the pond water during the spring tides allows entrance of nutrients with the incoming water. After each cropping, the ponds are drained and exposed to sunlight. Usually a heavy growth of benthic algae, predominantly blue-greens, develops immediately following this period.

Artificial feeding to a limited extent is also practised in Philippine milkfish ponds. Feed used as direct fish food undoubtedly serves also as fertilizer. Rice bran is the principal item used especially in milkfish pond nurseries. Corn bran, bakery wastes and cereal by-products are also used. Animal manures, especially poultry droppings, are generally applied when available as fertilizers. These are fed on directly by the fish.

The use of inorganic fertilizers is under investigation with some indications of success. Experiments in the use of 8-18-4 (N-P-K) in milkfish pond nurseries resulted in better growth of the fish food, greater stocking capacity of ponds (from 30 to 50 fry/m^2) and faster rate of growth of the milkfish fingerlings. In milkfish rearing ponds complete fertilization with 12-12-12 (N-P-K) was found to effect better growth of the algal food

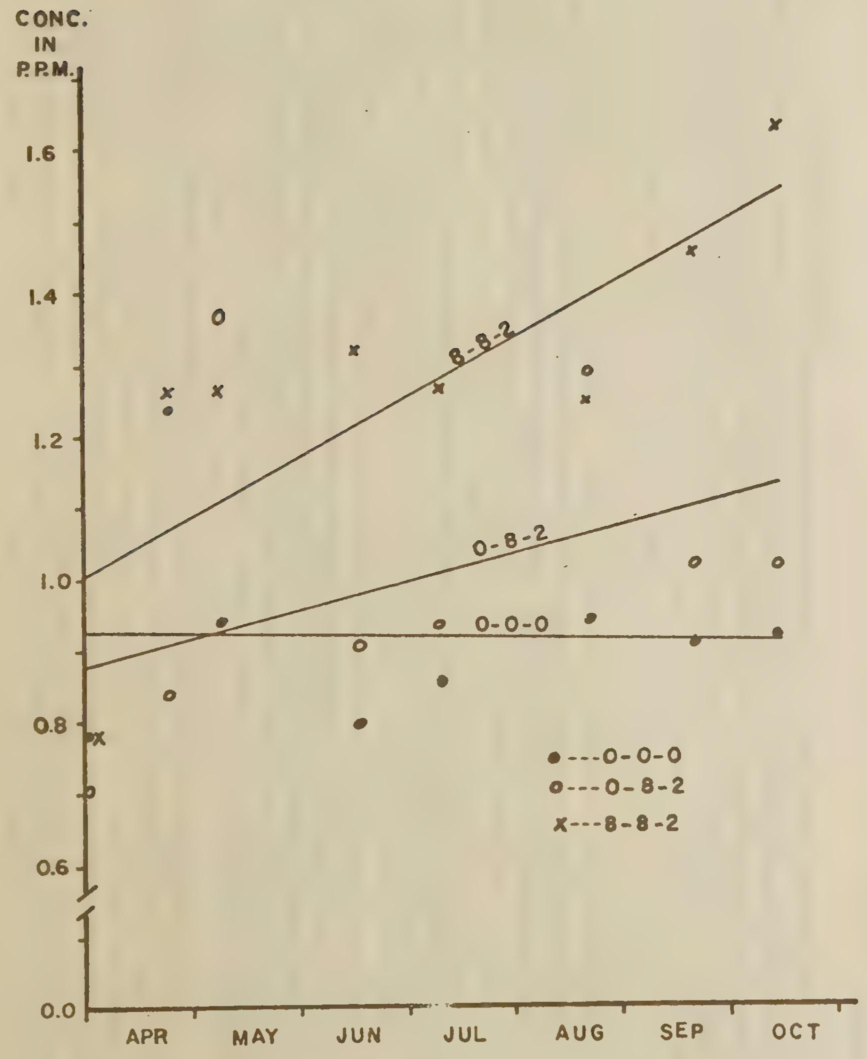
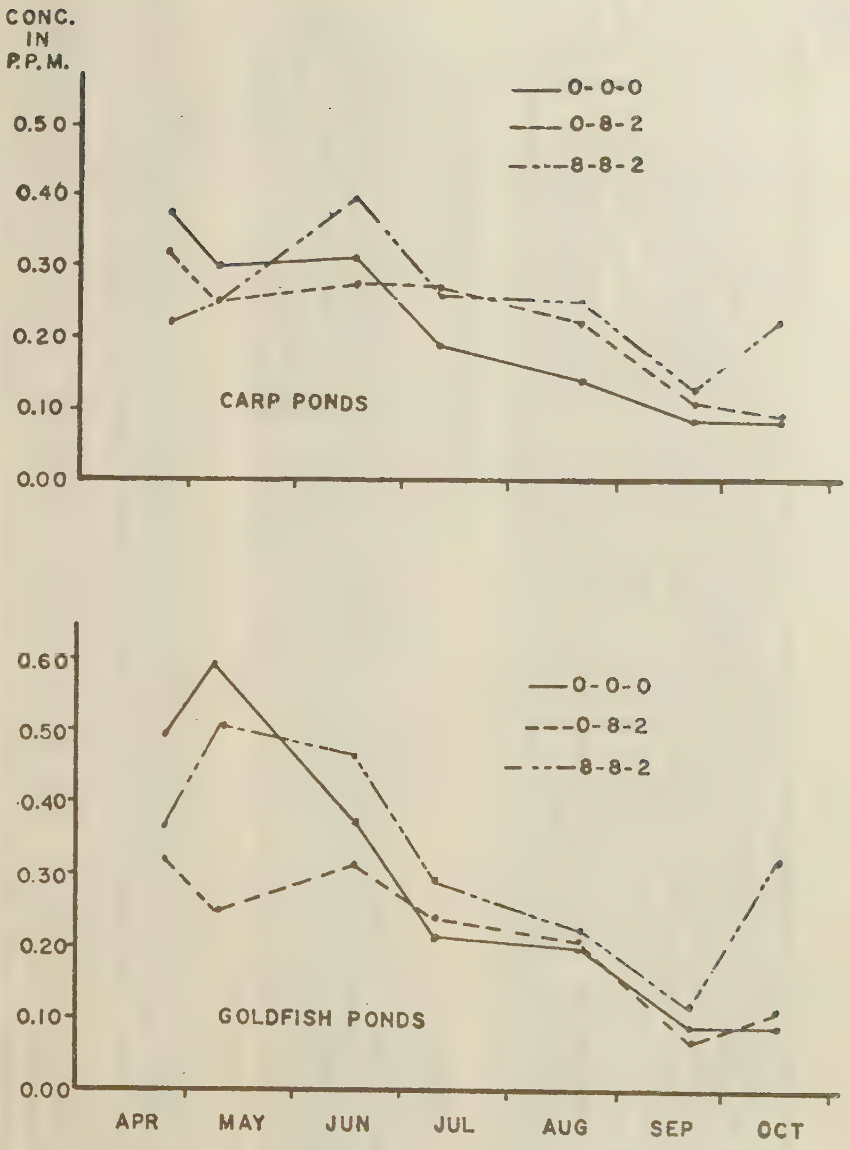


Fig. 1 Regression lines of total nitrogen content of pond waters receiving different fertilizer treatments



Figs. 2a and 2b Ammonia concentrations in carp and goldfish ponds receiving different fertilizer treatments of the milkfish. In experimental trials in one of the Philippine Fisheries Commission Fish Farm Stations for milkfish, repeated use of 16-20-0 (N-P-K) resulted in an average production of 1.3 tons/ha/year of fish. This is almost four times greater than the present average production from unfertilized ponds in this country.

As a result of the demonstrated successes of these experiments, the fertilization of ponds with inorganic substances is slowly being adopted. However, the restricted supply, and the prohibitive prices demanded for inorganic fertilizers, limit their general use.

2 RESULTS OF EXPERIMENTS ON INORGANIC FERTILIZERS MADE IN ALABAMA, U.S.A.

As a part of a continuing study on pond fertilization at the Farm Ponds Project, Agricultural Experiment Station of the Auburn University, Auburn, Alabama, the author carried on a year-round experiment during the 1959 crop period. The study was designed to test the effect of non-nitrogenous fertilization in ponds that had received continued complete fertilizers during the preceding 15-year period. Two species of fish, common carp and goldfish (Carassius auratus), were used separately in three fertilizer treatments, namely with 0-0-0, 0-8-2, and 8-8-2 pounds of N-P_2O_5-K_2O per acre [1] per application.

2.1 Effects on chemistry of pond water

The concentration of total nitrogen dissolved and in suspension in the water was related to the fertilization the ponds received; it was highest in the 8-8-2, followed next in the 0-8-2 and lowest in the 0-0-0 ponds. These differences in levels in the three treatments were significant. The amount of total nitrogen in each of the unfertilized ponds remained at more or less the same level throughout the experimental period. The 0-8-2 ponds gradually increased in their total nitrogen content toward the end, and that in the 8-8-2 increased at an even higher rate than in the 0-8-2 (Fig. 1).

The inorganic nitrogen component (ammonia plus nitrate) in all the ponds started at a relatively high level and gradually decreased toward the end of the experiment. Ammonia, the more abundant fraction, declined rapidly during the period (Figs. 2a and 2b). Nitrate was in minute quantities, but gradually increased during the experimental period (Figs. 3a and 3b). Close relationship between the decline and inorganic nitrogen on the one hand and the increase of plankton on the other was observed.

Ammonia and nitrate in ponds receiving similar fertilizer treatments differed significantly in levels in the carp and goldfish ponds. Ammonia concentration was lower in the carp ponds than in the goldfish ponds; as carp stir the pond bottom and muddy the water, more rapid absorption of ammonia on clay colloids probably took place (Figs. 2a and 2b). The nitrate concentrations were higher in the carp than in the goldfish ponds (Figs. 3a and 3b). This indicated less effective use of this nutrient for plankton production in the carp ponds, probably as a result of the muddy water.

The amounts of organic nitrogen in the fertilized 8-8-2 and 0-8-2 ponds were significantly higher than in the unfertilized ponds (Fig. 4). In the completely fertilized ponds (8-8-2) the concentration gradually increased and was significantly higher than in the phosphate-potash fertilized ponds (0-8-2). The organic nitrogen content of the 0-8-2 ponds fluctuated drastically during the experimental period with only a slight build-up toward the end of the experiment; in the 0-0-0 ponds it remained low, fluctuated and did not appear to have increased in level at the termination of the experiment (Fig.4).

The concentration of dissolved inorganic phosphorus in the pond waters was related to the fertilizer treatment; it was significantly higher in the 0-8-2 and 8-8-2 than in the unfertilized ponds (Figs. 5a and 5b). The disappearance of inorganic phosphorus from the pond water after its application was extremely rapid; it was being lost at the rate of 12.7 percent per day in the 0-8-2 and 14.3 percent per day in the 8-8-2 ponds (Fig. 6). The phosphorus content of the pond waters underwent unexplained cyclic changes during the experimental period (Figs. 5a and 5b).

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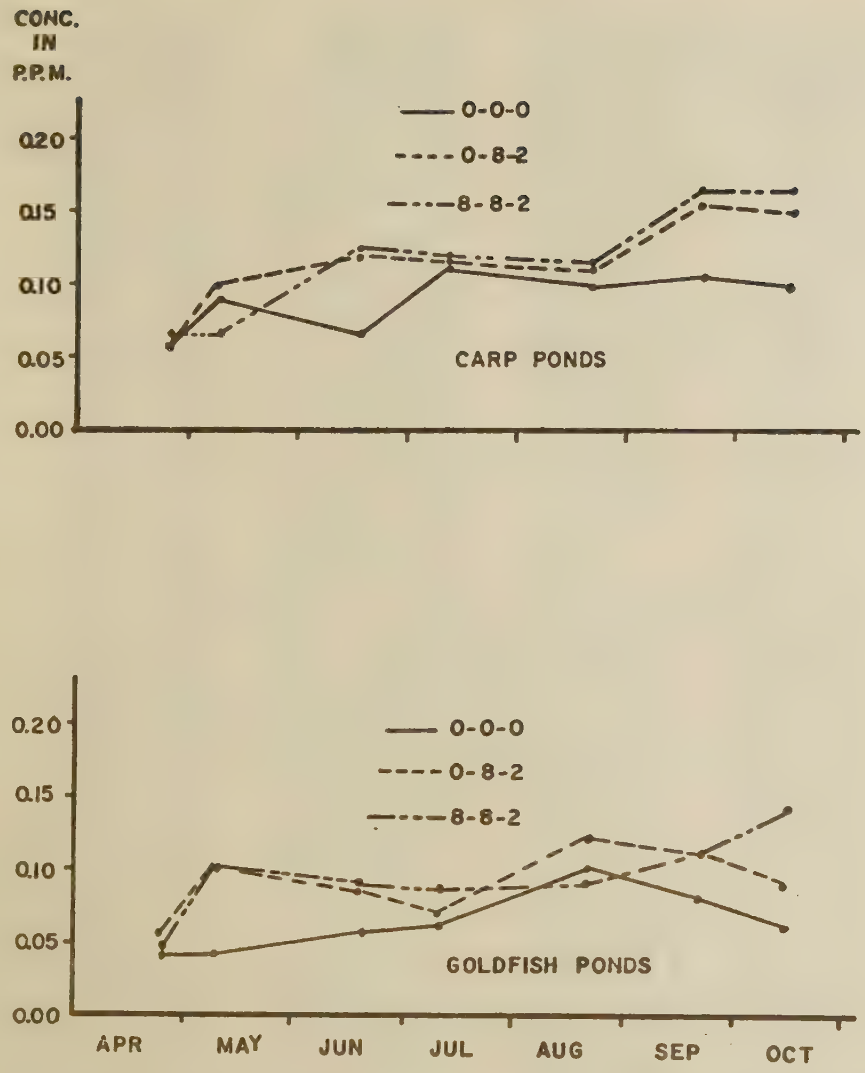
[1] lbs/acre x 1.12 = kg/ha



Figs. 3a and 3b Nitrate concentrations in carp and goldfish ponds receiving different fertilizer treatments

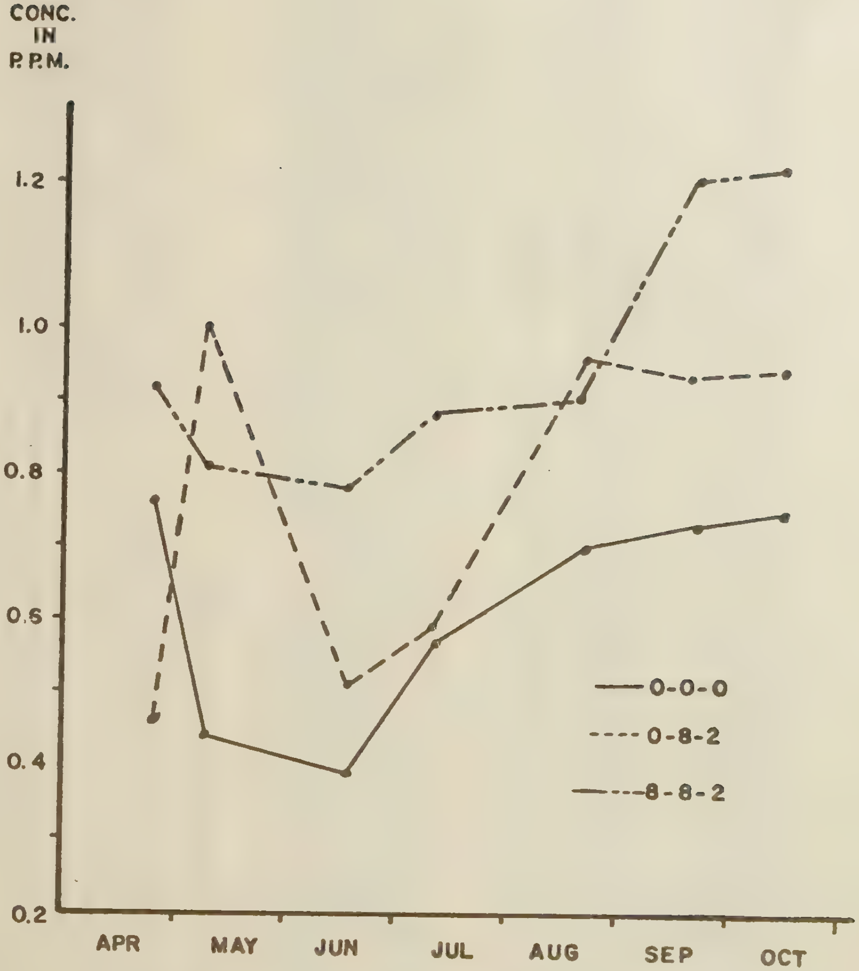
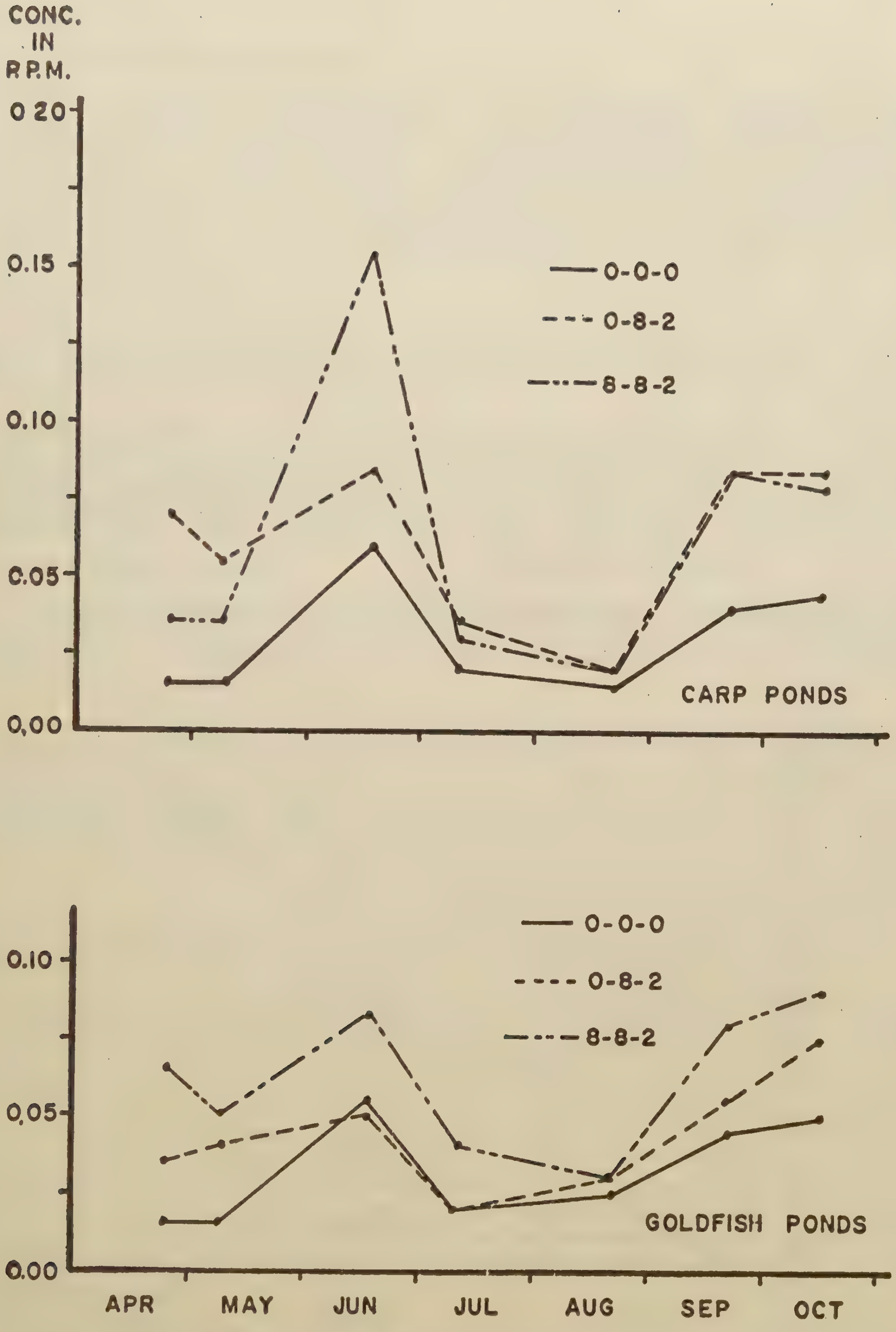


Fig. 4 Organic nitrogen concentrations in pond receiving different fertilizer treatments



Figs. 5a and 5b Phosphorus concentrations in carp and goldfish ponds receiving different fertilizer treatments

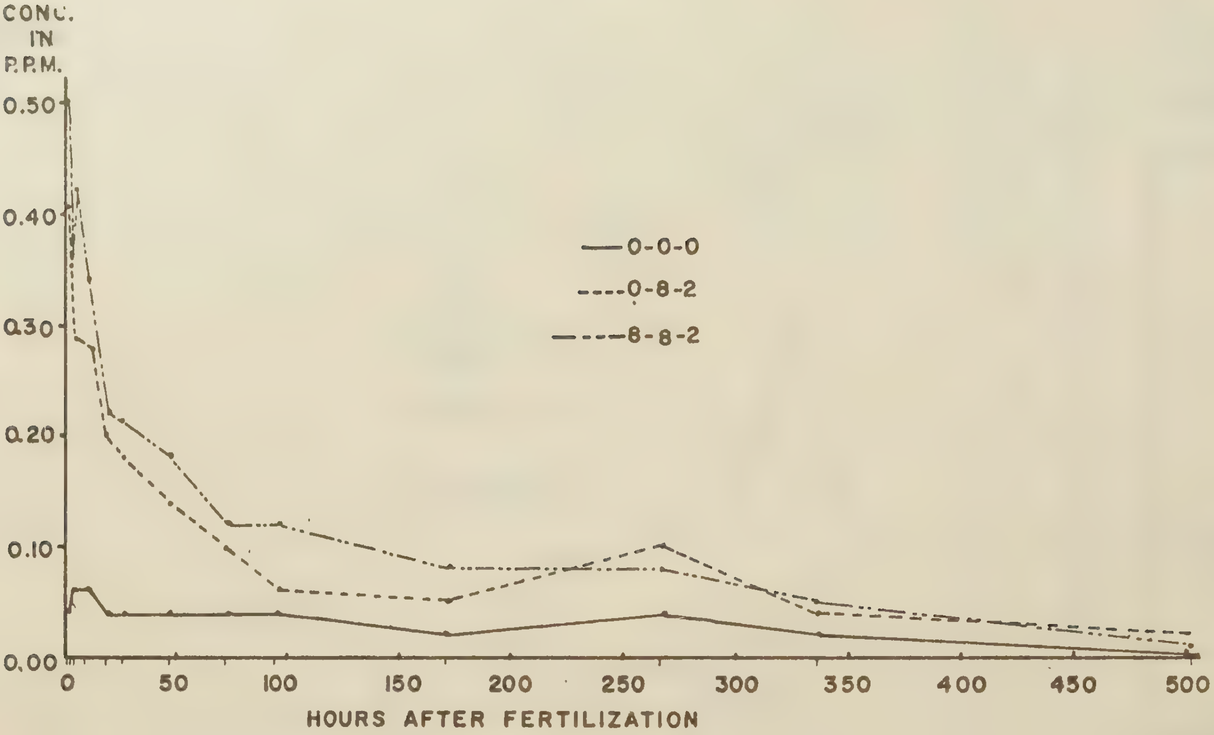


Fig. 6 Phosphorus in pond waters at selected intervals after the application of fertilizers

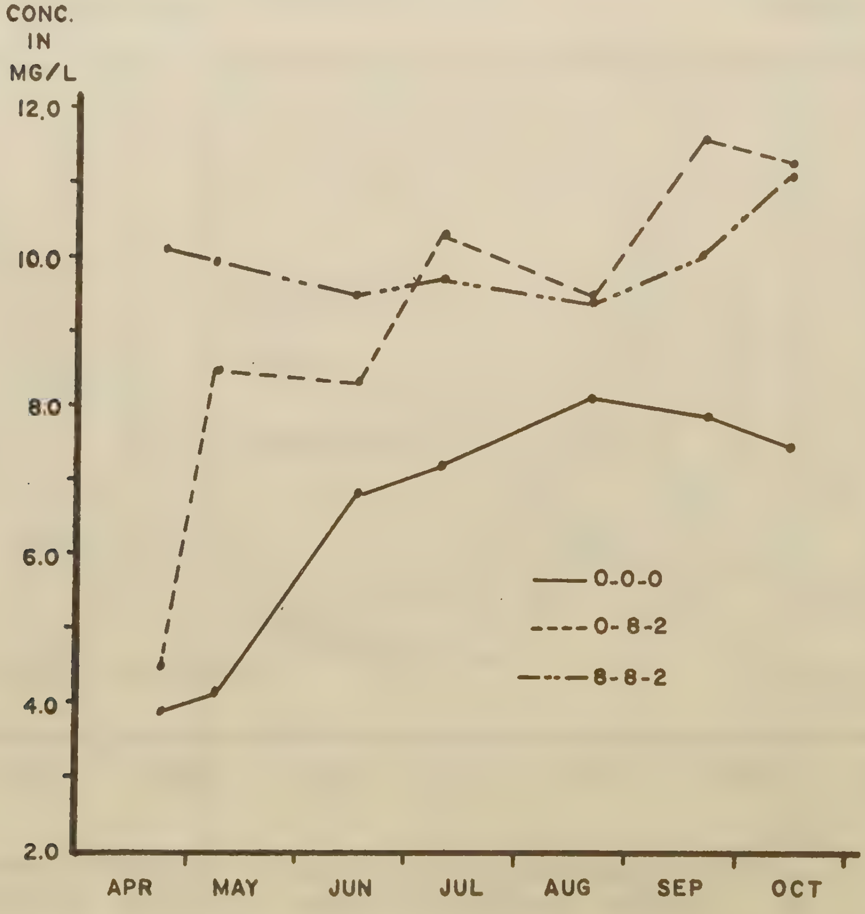


Fig. 7 Plankton in ponds receiving different fertilizer treatments

2.2 Plankton and bottom fauna

Carp utilized bottom fauna (mainly aquatic insects) more completely than goldfish (Table I). This was because carp feed heavily on bottom organisms while goldfish feed largely on plankton from the surface to the pond bottom. The amount of plankton and aquatic insects produced in the fertilized 8-8-2 and 0-8-2 ponds were significantly higher than in the unfertilized ponds (Fig. 7 and Table II). A trend was indicated in the averages per sampling period that the 8-8-2 ponds had higher amounts of plankton and aquatic insects than the 0-8-2 ponds, but the difference was not statistically significant.

2.3 Fish production

The production of fish, both carp and goldfish, was highest where complete fertilization was continued, followed next by phosphate-potash fertilization and lowest with no fertilization as indicated in Table III.

The increases in goldfish production resulting from 8-8-2 and 0-8-2 fertilizations were significant; the increases in carp production were not significant although the averages in the 8-8-2 and 0-8-2 were consistently higher than in the unfertilized ponds. More replications and a longer experimental period might raise the difference to a significant level.

2.4 General comments

Some residual effect of the continued yearly application of complete fertilizers in the ponds during the previous fifteen years was noted. The unfertilized ponds in this experiment were calculated to be producing 3.7 times more carp and 1.7 times more goldfish than in the original unfertilized state.

The fish, aquatic insects and plankton production of the ponds receiving different fertilizer treatments indicated that higher production resulted when fertilizers were applied. The chemical data tended to show that indigenous pond sources and/or fixation (in the case of nitrogen) cannot fully be relied upon to supply the needs of continued and intensified biological production; for better results, the application of a suitable formulation of complete fertilizers is imperative.

Table I

Ekman dredge sampling of bottom organisms (in milligrams dry weight per square foot (0.0929 sq.m.) of pond bottom)[1]

Period	Carp ponds			Goldfish ponds			Period totals
	0-0-0	0-8-2	8-8-2	0-0-0	0-8-2	8-8-2	
1. June	2.24	6.11	3.97	4.16	12.95	0.00	40.13
	0.00	0.32	1.81	1.28	2.90	4.39	
2. September	0.88	0.84	1.28	2.63	2.20	3.15	34.56
	0.11	2.56	2.13	8.33	0.53	9.92	
3. October	0.96	2.91	0.21	1.16	3.73	1.65	49.44
	0.96	3.84	5.32	13.39	3.91	11.40	
Treatment totals	5.15	16.58	14.72	30.95	26.22	30.51	
Totals in carp and goldfish ponds		36.45			87.68		

[1] Values are given for each of two ponds for each treatment

Table II

Relative volumes of aquatic insects from ponds receiving different fertilizer treatments collected from masonite plate collectors (milligrams per square foot (0.0929 sq.m.) of surface)1/

Period	Carp ponds			Goldfish ponds			Period totals
	0-0-0	0-8-2	8-8-2	0-0-0	0-8-2	8-8-2	
1. June	0.5 0.0	4.0 0.5	10.2 8.5	0.1 0.2	5.8 9.5	11.5 2.1	52.9
2. July	5.5 0.0	6.5 6.0	8.0 2.5	8.0 0.9	2.9 1.5	7.5 8.0	57.3
3. August	2.5 0.2	4.0 2.2	14.0 3.7	10.5 0.4	3.2 4.8	3.9 5.0	54.4
4. September-October	2.5 2.0	4.4 3.4	3.6 2.9	2.4 0.8	4.5 8.0	7.6 7.2	49.3
Treatment totals	13.2	31.0	53.4	23.3	40.2	52.8	
Totals in carp and goldfish ponds		97.6			116.3		

1/ Values are given for each of two ponds for each treatment.

Table III

Fish production in ponds receiving different fertilizer treatments

Fertilizer treatment	Average total production of ponds in kg/ha	
	Carp	Goldfish
0-0-0	305.6	469.5
0-8-2	347.1	684.6
8-8-2	387.5	778.5

3 REFERENCES

Bose, P.C., Calcutta sewage and fish culture. Proc.nat.Inst.Sci.India, 10(4):443-54
1944

Buschkiel, A L., Lehren aus tropisches Teichwirtschaft. Z.Fisch., 35:181
1937

Djajadiredja, R.R. and R. Amidjaja, Some observations on Chanos culture in fresh
1960 water. Proc.Indo-Pacif.Fish.Coun., 8(2):9-18

Fowler, D G., Utilization of sewage for fish culture in India. Proc.nat.Inst.Sci.India,
1944 10(4):463-7

Frey, D.G., The pond fisheries of the Philippines. J.Mar.Res.Yale Univ., 6:247-58
1947

Hickling, C.F., Fish farming in the Near and Middle East. Nature, Lond., 161:748
1948

Hoffman, W.E., Preliminary notes on the fresh water fish industry of South China,
1934 especially Kwangtung Province. Lingnan Univ.Sci.Bull., (5)

Hora, S.L., Fish farm objectives and requirements. J.Roy.Asiatic Soc.Bengal Sci., 11
1945 (2):99-117

__________, Pond culture of warm-water fishes. U.N. Sci.Conf.Cons.Ut.Res., 7:120-4
1951

Le Mare, D.W., Weeding in fish farming. Nature, Lond., 162:704
1948

Lin, S.Y., Fish culture in ponds in the New Territories of Hongkong. J.Hong Kong Fish.
1940 Res.Sta., 1(2):161-93

__________, Pond culture of warm-water fishes. U.N. Sci.Conf.Cons.Ut.Res., 7:131-5
1951

Malacca. Tropical Fish Culture Research Institute, Rep.trop.Fish Cult.Res.Inst.
1960 Malacca, 1960:28 p.

Matida, Y., Study of farm pond fish culture. 2. Chemical study on the effect of
1955 fertilizer to plankton production. Bull.Freshw.Fish.Res.Lab., Tokyo,
4(1):33-40

Nair, K.K., The effect of Calcutta sewage on fish life. Proc.nat.Inst.Sci.India, 10
1944 (4):455-62

Nakamura, K. et al., Possibility of carp fingerlings production in farm ponds. Nagano
1956 Prefecture, Ueda Branch Fresh Water Fish.Res.Lab., 6(2):49 p.

Padlan, P.G., Fertilization - Key to higher fish production. Fish.Gaz.Quezon City,
1960 4(3):2-9

Padlan, P.G. and L.V. Hosillos, A preliminary study on the effect of 12-12-12 (N-P-K)
1960 inorganic fertilizer on algae in brackish-waters. Report submitted to the
Bureau of Fisheries, Philippines, 1956, 7 p.

Rabanal, H.R., The culture of lab-lab the natural food of milkfish fry and fingerlings.
1949 Dept.Agri.Nat.Res.Tech.Bull., (18):9 p.

__________, Pond culture of warm-water fishes (with particular emphasis on bañgos
1951 or milkfish cultivation under Philippine conditions). Proc.U.N. Sci.Conf. Cons.Ut.Res., 7:142-5

__________, Mixed farming practices for rural areas in the Philippines. Fish.Gaz.
1957 Quezon City, 1(3):10-3

__________, The effect of no fertilization and non-nitrogenous fertilization upon
1960 the chemistry of water, the plankton, bottom organism and fish production in ponds that had received continued complete (N-P-K) fertilizers during the preceding 15-year period. Ph.D. dissertation submitted to the Graduate School, Auburn University, Auburn, Alabama, U.S.A.: 95 p.

Ronquillo, I.A. and A. de Jesus, Notes on growing of lab-lab in 'bañgos' nursery ponds.
1958 Proc.Indo-Pacif.Fish.Coun., 7(2/3):43

Schuster, W.H., Fish culture in brackish-water ponds of Java. Indo-Pacif.Fish.Coun.
1952 Special Bull., (1):143 p.

Shimadate, M. et al., Effect of fertilization and significance of artificial feeding
1957 to fish production in farm ponds, Shioda Plain. Nagano Prefecture, Ueda Fish.Res.Lab., 7(1):31 p.

Sulit, J.I., R.S. Esguerra and H.R. Rabanal, Fertilization of bañgos nursery ponds
1958 with commercial chemical fertilizer. Proc.Indo-Pacif.Fish.Coun., 7(2/3):44

Sunier, A.J.L., Contribution to the knowledge of the natural history of the marine
1922 fish ponds of Batavia, Treubia, 2(159)

Swingle, H.S., Experiments on pond fertilization. Bull.Ala.agric.Exp.Sta., (264):34 p.
1947

Swingle, H.S., B.C. Gooch and H.R. Rabanal, Phosphate Fertilization of Ponds. Trans.
1964 stheast.Ass.Game Fish Comm.,

Tang, Y.A. and T.P. Chen, The use of chemical fertilizers in milkfish ponds of Taiwan.
1957 Fish.Serv.jt Comm.rur.Reconstr.China, (3):20 p.

Vaas, K.F., Notes on fresh-water fish culture in domestic sewage in the tropics.
1948 Landbouwdocumentatie, 20

Vaas-van Oven, A., The use of 'marygold' (Tithonia diversifolia Gray) as green manure
1958 in Indonesian carp ponds. Proc.Indo-Pacif.Fish.Coun., 7(2/3):13-34

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FISH PRODUCTION IN SOME RURAL DEMONSTRATION PONDS IN MADRAS (INDIA) WITH AN ACCOUNT OF THE CHEMISTRY OF WATER AND SOIL

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FISH PRODUCTION IN SOME RURAL DEMONSTRATION PONDS IN MADRAS (INDIA) WITH AN ACCOUNT OF THE CHEMISTRY OF WATER AND SOIL

Abstract

The hydrological features and fish yield in more than fifty ponds in Madras State were studied and the ponds classified on the basis of certain ecological conditions - fort moats, temple tanks, rock pools, coastal ponds, large irrigation tanks and village ponds. Waters having permanent silt turbidity gave very low annual fish yields of less than 150 kg/ha. Even though shallow, large irrigation tanks with continuous inflow and outflow yielded less than 100 kg/ha/annum because of poor plankton development. When electrical conductivity was over 400 µ mhos, it did not limit productivity, but above this value productivity did not increase proportionately with conductivity. Most of the ponds studied had a total alkalinity over 150 ppm, total hardness over 100 ppm, calcium over 30.0 mg/l and a pH over 7.0. Soils with "available phosphorus" less than 0.5 ppm, pH less than 7.0 and calcium less than 50 ppm were in the low productive group. The fort moats, temple tanks and rock pools were highly productive waters, having permanent blooms of blue-green algae. The milkfish Chanos chanos and other herbivorous fishes grew well in these. The fort moats and temple tanks yielded more than 1000 kg/ha/annum. Combined culture of Tilapia sp. with Chanos and carps resulted in decreased yield. In tilapia ponds, intensive cropping yielded over 2,000 kg/ha/annum, but these were of fish less than 50 g each in weight. Ponds stocked with more than 10,000 fish per ha (especially 'major' carps) gave a production of over 1,000 kg/ha/annum.

PRODUCTION DE POISSON DANS CERTAINS ETANGS RURAUX DE DEMONSTRATION A MADRAS (INDE) ET ETUDE CHIMIQUE DE L'EAU ET DU SOL

Résumé

Il a été procédé à une étude des caractéristiques hydrologiques et du rendement en poisson de plus de cinquante étangs de l'Etat de Madras, classés en fonction de certaines conditions écologiques en fossés de forts, bassins de temples, trous d'eau rocheux, étangs côtiers, grands réservoirs d'irrigation et étangs de villages. Les eaux présentant une turbidité permanente due à la présence de particules de limon en suspension fournissent une production annuelle de poisson très faible, de l'ordre de moins de 150 kg/ha. Bien que peu profonds, les grands réservoirs d'irrigation avec alimentation et écoulement permanents produisent moins de 100 kg/ha/année à cause du faible développement du plancton. Il a été constaté qu'une conductivité électrique supérieure à 400 µ mhos ne limitait pas la productivité, mais qu'au-delà de cette valeur celle-ci n'augmentait pas proportionnellement à la conductivité. Dans la plupart des pièces d'eau étudiées, l'alcalinité totale était supérieure à 150 ppm, la dureté totale supérieure à 100 ppm, la teneur en calcium supérieure à 30,0 mg/l et le pH supérieur à 7,0. Les sols les moins productifs étaient ceux ayant une teneur en "phosphore disponible" inférieure à 0,5 ppm, un pH inférieur à 7,0 et une teneur en calcium inférieure à 50 ppm. Il a été observé que les fossés de forts, les bassins de temples et les trous d'eau rocheux contenaient les eaux les plus productives et qu'il s'y trouvait en permanence des fleurs d'eau d'algues bleues. Le Chanos chanos et autres poissons herbivores prospèrent dans ces eaux. Les fossés de fort et les bassins de temples fournissent un rendement de plus de 1 000 kg/ha/année. L'élevage de Tilapia sp., de Chanos et de carpes dans la même pièce d'eau a eu pour résultat de diminuer le rendement. Dans les étangs à Tilapia, une exploitation intensive a permis d'obtenir des rendements dépassant 2 000 kg/ha/année, mais s'agissait de poissons pesant moins de 50 g chacun. Des étangs chargés à plus de 10 000 poissons à l'hectare (notamment des 'major' carps) ont fourni une production de plus de 1 000 kg/ha/année.

PRODUCCION DE PESCADO EN ALGUNOS ESTANQUES RURALES DE DEMOSTRACION DE MADRAS (INDIA) JUNTO CON UNA RESEÑA DE LA QUIMICA DEL AGUA Y EL SUELO

Extracto

Se estudiaron las características hidrológicas y el rendimiento en peces de más de 50 estanques del Estado de Madras, los cuales se clasificaron sobre la base de ciertas condiciones ecológicas, por ejemplo, fosos de fuertes, estanques de templos, balsas de rocas, lagunas costeras, grandes embalses de riego y estanques de poblados. Las aguas que tenían una turbidez permanente debida a los sedimentos daban unos rendimientos anuales de peces muy bajos, inferiores a 150 kg/ha. Pero, incluso los grandes embalses de riego de poca profundidad con entrada y salida contínua de agua rindieron menos de 100 kg/ha/anuales debido a la escasez de plancton. Cuando la conductividad eléctrica era superior a 400 µ mhos, esto no limitó la productividad, pero, por encima de dicho valor, la productividad no aumentó proporcionalmente con la conductividad. La mayoría de los estanques estudiados tenían una alcalinidad total de más de 150 ppm, una "dureza" del agua superior a 100 ppm, calcio por encima de 30,0 mg/l y un pH superior a 7,0. Los suelos con "fósforo disponible" en cantidad menor a 0,5 ppm, un pH inferior a 7,0 y con menos calcio de 50 ppm figuraban en el grupo de baja productividad. Los fosos de fuertes, los estanques de los templos y las balsas de las rocas eran aguas muy productivas que tenían floraciones permanentes de algas verde-azules. El sabalote (Chanos chanos) y otros peces herbívoros se criaban bien en estas aguas. Los fosos de los fuertes y los estanques de los templos daban un rendimiento superior a 1.000 kg/ha/anuales. El cultivo combinado de Tilapia sp. con Chanos y carpas dió por resultado una disminución del rendimiento. En los estanques dedicados a Tilapia, el cultivo intensivo rindió más de 2.000 kg/ha/anuales, pero consistente en peces de menos de 50 gramos de peso cada uno. Los estanques poblados con más de 10.000 individuos por hectárea especialmente carpas "principales") dieron una producción superior a 1.000 kg/ha/anuales.

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1 INTRODUCTION

The Madras Fisheries Department pioneered the development of fisheries in rural areas, by establishing demonstration ponds in widely scattered parts of this State. There are more than a hundred such ponds of which more than half have been studied intensively with regard to their hydrobiological and edaphic conditions. Fish stocking and removals have also been recorded. Such complete details correlating fish yields with hydrobiological and soil conditions are not available for many other parts of the world. Hence the results of our studies are presented in this report.

2 POND FISH PRODUCTION IN VARIOUS COUNTRIES

Schuster et al., (1954) and Mortimer (1954) furnished comparative figures of fish production from a few selected countries, the ones noted for high yields being, Belgian Congo (2,000 kg/ha), Israel (1,650 kg/ha) and Indonesia (1,000 kg/ha). Recently production has increased in these and other countries. Sarig (1961) has recorded a yield of 1,550 to 2,270 kg/ha from Israel during 1960, which was an increase of 107 percent over the 1950 rate. Tal and Shelubsky (1952) reported that while in 1938, there were only ten ha of fish ponds in Israel, during 1950, it had increased to 3,000 ha yielding 5,000 tons of fish (1,700 kg/ha). Hurvitz (1960) records individual yields of 4,300 kg/ha from ponds in Heftsi-bah area of Israel. A striking increase of fish yield was reported by Prowse (1963) from Malaya, where a former production of 22.4 kg/ha in acidic cat-clay ponds was boosted to 1,680 kg/ha in three years by liming and application of superphosphate. Individual yields exceeded 2,200 kg/ha. By intensive feeding, 1,220 kg/ha carp were obtained from Eastern Germany (Schäperclaus, 1961a) and 2,548 kg/ha in Koncanica in Yugoslavia (Schäperclaus, 1961b), and 1,500 kg/ha in the Ukrainian Republic. (Michler and Schäperclaus, 1963). In Russia, net yields of 918 to 1,184 kg/ha of fish were obtained in ponds supplied with purified sewage, (Wolny, 1962). Timmerman (1960) reported a yield of 750 kg/ha in natural ponds in Lebanon which could be raised to 1,500 kg/ha by feeding. In Sudan, Huet (1959) noted a natural production of 500 kg/ha which could be raised to 2,500 kg/ha by intensive feeding. In the Congo, a yield of 4,325 kg/ha was normal in Kivu Province (Huet, 1957) but 70 percent of this was made up of Tilapia of sizes less than 15 cm. He also recorded the following yields - Katanga, 2,300 to 3,300 kg/ha; Orientale Province, 500 to 2,000 kg/ha, Ruanda-Urundi, 1,000 kg/ha and Equatoriale and Kasai Province 500 kg/ha. The Indonesian ponds produced 1,181 kg/ha, i.e., 24.139 tons in 20,441 ha (Huet, 1956). Combination of species increased the yield and supplemental feeding boosted the production to 5,000 kg/ha. Vaas (1948) had earlier noted that sewage-fertilized ponds yielded 3,009 kg/ha of carps. Staggering yields of 3,600 to 17,800 kg/ha were reported from Bangkhen farm in Thailand (Pongsuwana, 1957). Sreenivasan (1964) has described the ecology of ponds yielding over 1,000 kg/ha, one of them yielding over 5,000 kg/ha. In this paper, an account of fish production from over fifty ponds in the Madras State in India is discussed.

3 METHODS

Water samples were collected and analysed according to standard methods. Most of the ponds were visited on more than five occasions. Data on free carbon dioxide and CO_3'' were obtained but not included in Table I. Low bicarbonate values in some ponds is due to high CO_3'' values caused by intense photosynthesis in phytoplankton-rich waters. Nitrates and inorganic phosphate were present in very rare instances and are omitted from Table I. Soil testing was done by the Spurway (1944) method. In some soils, detailed analysis was done according to Piper (1950). Plankton was collected with a nylon net of 120 to 150 mesh/in (50 to 60 mesh/cm).

4 TYPES OF PONDS AND THEIR PHYSICO-CHEMICAL CONDITIONS

The ponds studied were divided into six types according to their use. They were (i) fort moats, (ii) temple tanks, (iii) rock pools, (iv) coastal ponds, (v) large irrigation tanks and (vi) other village ponds. The majority of the ponds had an area of 0.4 to 1.6 ha (one to four acres); only two tanks were over 50 ha.

4.1 Fort moats

The fort moats are excavated ditches around old forts, the rock walls of the fort forming one side of the ponds. The opposite side may also be a stone-built wall, as in Vellore fort moat, or merely a sloping earthern embankment as in Arni fort moat. The run-off water accumulates in these after rain and the perennial ones also have underground springs. These fort moat waters are virtually 'derelict', used only for washing cattle. Quite often the sewage from the town is let into these ponds, which act as 'sewage oxidation ponds" (Sreenivasan, 1964a). Heavy organic growths occur as blooms of blue-green algae. The bicarbonate (methyl orange alkalinity) content of these is very high, often over 200 ppm. In summer the phenolphthalein alkalinity is high and sometimes hydroxide alkalinity also ensues. High hardness and very high electrical conductivity (dissolved solids) also characterize these waters. The calcium and chloride content were not high, but the pH value was rather high (over 8.5). Fluctuations in dissolved oxygen were common, with very low values in the morning and supersaturation values in the afternoon, indicating the high metabolic rates caused by the activities of photosynthetic algae. A permanent bloom of blue-green algae all round the year was a characteristic of these waters, the dominant forms being *Microcystis*, *Merismopedia*, *Oscillatoria*, *Nostoc*, *Spirulina*, etc. Fairly abundant zooplankton also occurs in these ponds. Fishes grow well in these waters and when stocked with planktophagous species,good yields ensued. *Chanos* was found to fare well in the fort moat waters, a growth of at least 500 g/year being obtained. Bottom fauna was fairly abundant in these ponds, and fishes feeding at this trophic level (for example, *Cyprinus carpio*) grew well. Except in Arni fort moat, the fish yield has been over 1,000 kg/ha/annum. Because of excessive blooms of plankton, high rates of stocking with plankton-feeders like *Chanos chanos*, *Cirrhina cirrhosa*, *C. mrigala*, *Catla catla*, etc., gave good results. This is one way of removing the ever-increasing organic matter. Low rates of stocking have been futile. Fish mortalities may occur in these ponds, but this has not affected the final yields.

4.2 Temple tanks

These are ponds paved with stones on the banks and gradually sloping towards the centre. The water is thus in contact with soil only for half its area. The temple tanks are not subject to sewage pollution, but are generally used for bathing and washing clothes. They have inlets to admit storm water but outlets rarely exist, or at best overflows exist at higher levels. The water stagnates over years and both organic matter and inorganic materials accumulate. These temple tanks are indistinguishable from fort moats in their chemical conditions. They have high methyl orange alkalinity, high hardness, high electrical conductivity, and moderately high calcium. The pH value is invariably high, reaching over 9.6. Diurnal fluctuations in dissolved oxygen, alkalinity and pH are common. Fish mortalities are recurrent in some of the temple tanks. Blooms of blue-green algae occur throughout the year, along with other groups such as *Scenedesmus* and in a few cases *Botryococcus*. Zooplankters are abundant too.

4.3 Rock pools

These "quarry" pools are formed by the excavation of rocks for building purposes and the pits formed get filled up by rains and by storm water. Silt settles in the course of time. In the absence of underground springs, the only source of water is precipitation and run-off from catchments. They have no inlets or outlets. Continued concentration of dissolved solids by evaporation results in a high chloride content and high electrical conductivity. The bicarbonate alkalinity is high, as in the fort moats and temple tanks. But the chloride, electrical conductivity, and pH are higher. Hardness was a little less than in those types of waters. Calcium content is fairly high. The plankton of these rock pools is similar to that in the fort moats and temple tanks, with blue-green algae dominating, the common genera in a bloom being *Microcystis*, *Oscillatoria* and *Merismopedia*.

4.4 The coastal ponds

These ponds are situated near the sea coast in deltaic areas. They receive supplies of fresh water and hence have a low chlorinity. The bicarbonate content is fairly high, as is also the hardness, which is higher than in rock pools and temple tanks. The electrical conductivity is very high, the high level of solutes being due to the saline influence. The pH is alkaline and calcium content is fairly high. These ponds develop dense growths of submerged weeds like Najas, Chara, Hydrilla, etc., and of emergents like Nymphaea and Nelumbium spp.

4.5 Large irrigation tanks

Two of these studied are small impoundments used for irrigation. Water from seepage channels or streams flows into the tanks (Odathurai and Ananthasagaram). After storage the water is used for irrigation of crops. There is a continuous inflow of water for about eight months a year and an outflow for a similar period. Algal blooms do not develop because the water is detained for only a short time, and due to the absence of pollution. One tank (Tamaraikulam) gets its water only from rain, and being shallow, has many submerged weeds. The other two larger tanks though very shallow are turbid and hence submerged weeds do not grow in them. The mean depth of Odathurai and Ananthasagaram is hardly 1.5 m.

4.6 Village ponds

This category includes all rural ponds not falling under the above five categories. All of the ponds are artificially created ones and used for bathing, washing clothes, etc. Only a few of them are polluted by human excreta and sewage, Chettikulam, Kumundankulam, Vairanachi Oorani, K.C. Kulam and Veppankulam. The ponds had fairly high bicarbonate, moderate hardness and fairly high electrical conductivity. Chlorinity was not high. The pH was not uniform in all the ponds, and varied widely, but most of them were on the alkaline side. Calcium content was not high in most of the ponds. There was no common feature in plankton composition and no two ponds were alike in this respect. Some of the ponds like Nathapallam, Chettinad moat described here, and Tirukkulam of Varappoor, and Nallathannikulam of Arni, are permanently turbid due to suspended inorganic matter and very little phytoplankton development takes place in these, and these are highly unproductive. Vellaikulam of Kancheepuram has a colloidal suspension causing turbidity.

5 FISH YIELDS RELATED TO WATER AND SOIL CHEMISTRY AND STOCKING RATES

Fifty-six ponds for which fairly adequate data on stocking and exploitation are available are dealt with in this paper. The figures furnished are the average of at least seven years data in most of the cases.

5.1 Water quality

Ponds ranged in production from 45 kg/ha to 5,486 kg/ha. In Table III the ponds are arranged in four groups on the basis of annual yield. These categories are discussed below. Twenty ponds yielded more than 1,000 kg/ha. All these ponds had bicarbonate content over 180 ppm (as HCO_3), and all except four had hardness (as $CaCo_3$) exceeding 100. The majority of ponds in this category had calcium content of over 50 mg/l, while the electrical conductivity was generally over 500 μ mhos. Only one pond had electrical conductivity less than 200.

The second category which includes 13 ponds, yielded 500 to 999 kg/ha. In this group, the bicarbonate content was less than 180 ppm in the majority of ponds, but over 100 ppm in all but three ponds. The hardness was less than 100 ppm in half the ponds. Only in three ponds was the Ca over 50 ppm. The electrical conductivity was however high, due to chlorides.

In the third category are included 21 ponds yielding 100 to 499 kg/ha. The bicarbonate content in these was high and does not correlate with the fish yield. A few ponds had hardness less than 100 ppm, but the majority had a hardness over 100 ppm. The calcium content of most of the ponds was less than 50 mg/l. The electrical conductivity was high and not correlated with yield.

In the fourth category only three ponds with yield less than 100 kg/ha are included. Two of these have areas exceeding 100 acres (40 ha) though shallow (average depth only 1.5 m). All the three ponds are permanently turbid due to suspended inorganic matter.

5.2 Soil conditions

In Table IV the soil nutrients of the ponds are tabulated according to decreasing levels of productivity, four categories being chosen. As seen in Table III, with regard to soil conditions, the first category had soils with available phosphorus over 0.75 ppm in the majority of ponds. The second category ponds also had similar phosphate contents. Contents of calcium, magnesium, ammonia, etc., were also similar. All these soils had a pH over 7.0 and many had a pH over 8.0. In the low productivity categories 3 and 4, the pH was lower and the phosphorus was not as high as in the other two groups. Low calcium is noticeable in some ponds in these categories.

5.3 Fish stocking

From Table II it can be seen that stocking rates do influence the yield in ponds. Ponds in Tanjore district are well stocked with species such as Catla catla, Cirrhina mrigala, Labeo firmbriatus, Cirrhina cirrhosa, etc. Natural stocking from the river system also takes place. The reasons for high productivity in Webster moat, Tanjore, have been discussed by Sreenivasan (1960). Since some other ponds listed here are equally productive as judged by water quality, soil condition, etc., the high yield in Webster moat has to be ascribed to the high rate of stocking. This applies also to the other ponds of Tanjore district - West moat, Sengulam, Ayyankulam, Ayikulam, Pidarikulam, Anaiyadikulam, Tirukulam, etc. The fish yields in coastal ponds of Adirampatnam and Negapattinam are not very high - in these the rate of stocking is low and the ponds are weed infested. It is of special interest that the chloride content of these ponds was low and so high chloride could not be the reason for the lower yields.

6 DISCUSSION OF SOME INDIVIDUAL PONDS

Kallukatti tank in Karaikudi, a 1/2 acre (0.2 ha) pond continuously yielded over 3,000 kg/ha. This is a typical Tilapia pond from which the catches consist of small-sized Tilapia of weights less than 35.0 g each. Economic fishes such as catla, Labeo sp., milkfish (Chanos) etc., did not thrive and grow well because of the severe competition from millions of Tilapia. Other ponds of similar Tilapia yields are Valaiveesi Teppam, Mariamman Teppam, K.C. Kulam, Vairanachi Oorani and the Pudokkottai ponds. In all these large numbers of small Tilapia make up the yield. Vellore fort moat and Ayyangulam, Tiruvannamalai are productive ponds which have given sustained yields of over 1,500 kg/ha and 1,400 kg/ha, respectively for many continuous years. It has been pointed out (Sreenivasan, 1964) that quite a high percentage of the primary production has been utilized in Vellore fort moat. Chinglepat fort moat, for all the high productivity, is too shallow (average depth 1.0 m) and this diminishes the carrying capacity. Growth of fish is however good. Tirukulam of Sirkali, shows a high yield of 1,800 kg/ha, but is made up of a large number of major carps of small size. The same result could have been achieved by lower stocking rates of major carps. In many ponds, yield of Chanos and major carps decreased after the introduction of Tilapia - Thearthankulam, Arni fort moat, etc.

The effect of size and depth of ponds is reflected in the three rock pools of Virdunagar, which are all very close to each other. Quarry pool I is shallow with an area of 0.45 acres (0.16 ha) and average depth of 1.5 m, and gives a yield of 797 kg/ha. Quarry pool II has an area of 0.65 acres (0.28 ha) and average depth of 2.0 m, and yields 489 kg/ha, while quarry pool III, having an area of 3.0 acres (1.2 ha) and average depth of 5 m, yields only 240 kg/ha. In all these ponds introduction of Tilapia ruined the culture of Chanos and major carps. Carlander (1951) recorded a catch of 1,235 lbs per acre (1,383.2 kg/ha) from 4.5 acre (1.8 ha) gravel pits. Deep temple tanks without shallow margins, for example Pallavankulam and Teppakulam of Sivaganga, also yield less, despite good chemical conditions of the waters. The two large irrigation tanks, Odathurai and Ananthasagaram gave very low yields of 67 and 56 kg/ha respectively. Though both are shallow, the vast area, the low stocking rate (with very few major carps), the wind induced turbulence causing water turbidity by bringing up the silt from the bottom, and the continuous inflow and outflow all contribute to the very low yields. Yount (1963) is of the opinion that aeration reduces productivity, by locking up the nutrients. Even this yield is mainly due to Tilapia (large-sized ones), indigenous catfishes, and minor carps like Labeo fimbriatus and Cirrhina cirrhosa. Permanently turbid waters like Chettinad moat, Nallathannikulam, and Tirukulam of Varappoor give very low fish yields. Nathapallam, a similar pond in Pudukkottai yielded 150 kg/ha mainly through Tilapia, though catla did not thrive for want of plankton. Vellaikulam in Kancheepuram is also a turbid water which had fairly good zooplankton population but poor phytoplankton. Ganapati and Chacko (1951) recorded good growth of stray catla, but poor plankton growth restricts even moderate yields. The yield of 485 kg/ha in Chettinad ponds was the result of fertilization with inorganic fertilizers. Even intermittent fertilization with superphosphate has increased the yield from less than 150 kg/ha prior to 1962 to 485 kg/ha from 1963.

Wherever Tilapia has been combined with Catla and Chanos in productive ponds, the yield has been depressed and both Chanos and Catla could not be obtained in the catches. In overpopulated Tilapia ponds of Pudukkottai very intensive fishing for removal of Tilapia resulted in very high yields (similar to Kallukatti pond in Karaikudi).

7 ATTEMPTS TO CLASSIFY FISH PONDS AND TO CORRELATE PRODUCTION WITH POND TYPES

Very few attempts have been made to classify fish ponds. Ganapati and Chacko (1950) made a tentative classification of fish ponds into five types and predicted the fish yields that could be obtained from each of these. Waters (1957) established a relationship between bicarbonate content of water and fish production. Ball (1948) similarly found a positive correlation between alkalinity and fish production, lakes with alkalinity over 150 ppm being highly productive. Barrett (1953) found that hard waters were more productive than soft waters and that phosphorus regeneration was better in waters of high alkalinity. Northcote and Larkin (1958) found that fish production was proportional to total dissolved solids. They found that a total dissolved solids content above 250 ppm produced abundant bottom fauna. Larger gill net catches were noted in lakes with total dissolved salts over 100 ppm. Dissolved nutrients must rank as a primary factor in determining levels of productivity. Soong Min Kong (1951) found that an alkaline reserve of 3.5 was optimum for fish production. A positive correlation between the methyl orange alkalinity content and the standing crop of fish was observed by Carlander (1955) and Slack (1955). Moyle (1954) observed that hard water lakes are more productive than soft water lakes, but suggests that calcium is not a critical factor in productivity. He used four indices, total phosphorus, total nitrogen, total alkalinity and salinity, to correlate with fish production. Chacko and Ganapati (1949) stated that a minimum of 650 ppm of calcium carbonate is essential for good fish production but this is erroneous because this level of alkalinity will be detrimental to fish. Hayes (1957) worked out a 'productivity index' for some Canadian lakes but he found no relationship between depth and productivity of bottom fauna.

In all the ponds studied by us, only four had bicarbonate alkalinity less than 100 ppm and only nine less than 150 ppm Only eight of the ponds had calcium less than 25 mg/l. With regard to hardness, all except two had more than 50 ppm hardness; most of the ponds had a hardness over 100 ppm. Only two ponds had electrical conductivity less than 250 µ mho. On the basis of alkalinity, Philipose (1960) divided fish pond waters into three categories and correlated these with the plankton production. However, when fish yield is one of the factors considered, his classification is not helpful. The ponds we have to deal with are all very 'productive' judged by soil and water conditions. The pH value alone would indicate this. Only one thing is clear, namely that permanently turbid waters carrying suspended inorganic or colloidal matter are very unproductive and yield less than 100 kg/ha. Stocking with Tilapia will slightly increase the yield.

Soils with 'available phosphorus' less than 0.5 ppm are definitely in the low productive group ($<$ 500 kg/ha). Those having phosphorus between 0.5 to 1.0 ppm are in the moderately productive group (500 to 1,000 kg/ha). Soils with available phosphorus of over 100 ppm are in the highly productive group ($>$ 1,000 kg/ha). Soil calcium was low in the low productive groups, generally less than 100 mg/l, and soil pH values were comparatively low in this group.

From the results obtained in Madras ponds, no clear-cut and well-defined classification is possible. Most of the ponds appear to be chemically productive. One fact, however, is clear, ponds stocked with planktophagous and fast-growing fish such as Chanos chanos, Catla catla, Cirrhina mrigala, Labeo fimbriatus, Cirrhina cirrhosa, Labeo calbasu, etc., in large numbers give good yields. Some ponds with abundant phytoplankton failed to give high yields of fish because of poor stocking or due to mixing Tilapia with carps and Chanos. However, some ponds with Tilapia have given high yields when cropped intensively. The temple tanks, fort moats, rock pools and some rural ponds are highly productive of fish although no artificial feed is given, because of direct or indirect organic pollution. Fish is one form in which this stock of nutrients could be removed (Yount, 1963). The only ponds which were fertilized were the unproductive Chettinad ponds where occasional applications of superphosphate boosted the yield more than four times. For unfertilized and unfed fish ponds the production recorded for most of the ponds in this paper is fairly high.

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9 REFERENCES

Ball, R.C., A summary of experiments in Michigan Lakes, on the elimination of fish popula-
1948 tions with rotenone 1934-42. Trans.Amer.Fish.Soc., 75:139-46

Barrett, P.H., Relationships between alkalinity and adsorption and regeneration of added
1953 phosphorus in fertilized trout lakes. Trans.Amer.Fish.Soc., 82:78-90

Carlander, K.D., An unusually large population of fish in a gravel pit lake. J.Iowa.Acad.
1951 Sci., 58:435-40

__________, Standing crop of fish in Lakes. J.Fish.Res.Bd Can., 12(4):543-70
1955

Chacko, P.I. and S.V. Ganapathi, Increased fish production in inland waters. Indian Geog.J.
1949 24(4):1-10

__________, Remarkable growth of the carp, Catla catla in a tank in Kancheepuram. Sci.
1950a Cult., 15:484

__________, Suggestions for stocking fish ponds in Madras. Madras agric.J., 37(5):1-5
1950b

Hayes, F.R., On the variation in bottom fauna and fish yield in relation to trophic level
1957 and lake dimensions. J.Fish.Res.Bd Can., 14(1):1-32

Huet, M., Aperçu de la pisciculture en Indonesie. Trav.Sta.Rech.Groenendaal (D), (19):1-55
1956

Huet, M., Dix annees de pisciculture en Congo belge et en Ruand-Urundi. *Trav.Sta.Rech.*
1957 *Groenendaal (D)*, (22):1-159

___________, Technical assistance mission to Sudan. *Trav.Sta.Rech.Groenendaal (D)*,
1959 (21):1-33

Hurvitz, Fish culture in deep-water ponds. *Bamidgeh*, 12(2):43-8
1960

Mortimer, C.H. and C.F.Hickling, Fertilizers in fish ponds. *Fish.Publ.Lond.*, (5):155 p.
1954

Moyle, J.B., Some aspects of the chemistry of Minnesota surface waters as related to
1954 game and fish management. *J.Wildl.Mgmt.*, 20(3):303-20

Michler and W. Schäperclaus, Ergebnisse und Probleme der Karpfenteichwitschaft in der udSSR.
1963 *Dtsch.Fisch.Ztg.*, 10(1):1-21

Northcote, T.G. and P.A. Larkin, Indices of productivity in British Columbia lakes.
1958 *J.Fish.Res.Bd.Can.*, 13(4):515-40

Philipose, M.T., Freshwater phytoplankton of inland fisheries. *In* Proceedings of the
1960 symposium on algology, New Delhi, ICAR, pp. 272-91

Piper, C. S., Soil and plant analysis, New York, Academic Press
1950

Pongsuwana, U., Production of *Tilapia mossambica* in experimental pond at Bangkhen.
1957 *Proc.Indo-Pacif.Fish.Coun.*, 6(2):197

Prowse, G.A., Neglected aspects of fish culture. *Curr.Aff.Bull.Indo-Pacif.Fish.Coun.*,
1963 (36):1-9

Sarig, S., Fisheries and fish culture in Israel in 1960. *Bamidgeh*, 13(3/4):61-76
1961

Schäperclaus, W., Versuche zur Ertragssteigerung von Karpfenteichen durch Erhöhung der
1961a Besatzstärke und der Fütterungen in Jahre 1960. *Dtsch.Fisch.Ztg.*, 8(3):79-85

___________, Aus der Teichwitrschaft Jugoslaviens. *Dtsch.Fisch.Ztg.* 8(5):137-44
1961b

Schuster, W.H., G.L. Kesteven and G.E.P. Collins, Fish farming and inland fishery
1954 management in rural economy. *FAO Fish.Stud.*, (3)

Slack, K.V., A study of the factors affecting stream productivity by comparative methods.
1955 *Invest.Ind.Lakes*, 4(1):13-48

Spurway, M., Soil testing. *Tech.Bull.Mich.(St.Coll.)agric.Exp.Stn.*, (132)
1944

Sreenivasan, A., Limnological features of and primary production in a polluted moat at
1964 Vellore, *Environm.Health*, 6(4):237-45

___________, High productivity of some tanks in Tanjore. *Rep.Madras Fish.Sta.*,
1960 (1955-1959):150-5

Tal, S. and M. Schelubsky, Review of fish farming industry in Israel. *Trans.Amer.Fish.Soc.*,
1952 81:218-23

Timmerman, A., L'Elevage de la carpe en Liban. Trav.Sta.Rech.Groenendaal (D), (21):1-33
1960

Upadhyaya, M.P., Calcium content of some fishery waters of Uttar Pradesh. Indian J.vet.Sci.,
1955 25(4):341-5

Vaas, K.F., Notes on fresh water fish culture in domestic seewage in Tropics.
1948 Landbouwirt, 20:331-48

Waters, T.F., Effect of lime application to acid bog lakes in northern Michigan.
1957 Trans.Amer.Fish.Soc., 86:329

Wolny, A., The use of purified town sewage for fish rearing. Roczn.Nauk.rol.(B), 81(2):231-49
1962

Yount, J.L., Causes and relief of hyper eutrophication of lakes. Progr.Rep.ent.Res.Cnt.Fla.,
1963 Oct.'60-Dec.'62, 25 p. (mimeo)

Table I

Chemical conditions in the rural fishery demonstration ponds

1	Area of water (ha) 2	Bicarbonates ppm 3	Hardness as Ca(O$_3$ ppc 4	Electrical conductivityμ mho. 5	Chloride ppm 6	pH	Dissolved oxygen mg/ℓ 8	Calcium mg/ℓ 9	Location 10
A. Fort moat ponds									
Vellore fort moat	4.9	30.5-256.2	166-490	1125-2500	118-560	8.8-9.6	1.7-27.0	47.6-27.0	Vellore, N.Arcot District
Webster moat	1.6	102.0-220.0	114-170	695	52-180	7.3-9-5	0.1-12.4	36.0-61.5	Tanjore, Tanjore District
Chinglepat fort moat	2.4	152.5-432.0	113-350	630-1150	80-124	7.9-8.7	2.0-16.6	20.8-34.1	Chinglepat, Chinglepat Dist
Arni fort moat	2.4	107.0-256.0	150-228	610-1900	160	9.3	4.8-5.2	25.5	Arni, N. Arcot District
West moat	0.8	92.0-183.0	104	490-375	74-91	7.2-7.5	0.7	52.1	Tanjore, Tanjore District
B. Temple tanks									
Mariamman Teppam	6.9	451.0-156.0	182-200	2650	298-388	8.7-9.6	0.9-4.4	61.1	Madurai, Madurai district
Sarvatheertham	1.6	98.5-214.0	-	460	86-310	8.9	0.7-9.5	33.6	Kancheepuram, Chinglepat "
Ayyangulam-Tiruvannamalai	1.6	217.0-226.0	66.300	800-1350	220-320	7.6-9.6	5.5-15.6	43.8	North Arcot district
Teppakulem-Sivaganga	2.4	104.0-201.0	80	900	160	7.4-8.8	0.0-1.3	34.1	Ramnad district
Tirukulam-Sirkali	0.4	189.1	92	380	48	7.5	0.5	4.7	Tanjore district
Pallavankulam	0.5	97.6-176.0	50-90	170-375	36-74	7.7-8.8	3.8	95.2	Pudukkottai, Trichy district
Ayyankulam-Tanjore	0.8	88.5-220.0	104	490	74-91	7.2-7.5	0	52.1	Tanjore district
Anaiyadikulam	0.4	378.2-607.2	290-360	1950	390	8.8-9.2	2.9-9.4	21.4	Tanjore, Tanjore district
Kallukatti Tank	0.2	101.0-183.0	120-154	475	111-244	7.1-9.6	0.0-15.5	26.2-36.0	Karaikudi, Ramnad district
Sengulam	1.6	116.0-281.0	144-170	890	62-156	7.3-8.3	6.5	19.6-46.1	Mannargudi, Tanjore "
C. Rock pools									
Virudunagar									
Quarry pool I	0.16	167.8	70	2125	536	9.0	9.8	44.1	Virudunagar, Ramnad "
Quarry pool II	0.28	326.0	34	3000	916	9.2	5.2	34.1	" " "
Quarry pool III	1.20	219.6	134	725	116-130	8.3	6.0	34.1	" " "
Rettaikulam	0.7	184.0-186.0	40.79	290-1675	61-400	8.6-9.5	6.0-9.2	135.2	Pudukkottai, Trichy "
Periakulam	1.1	76.3-242.0	222	3000	216-1050	9.35	7.4	69.8	" " "
D. Coastal ponds									
Katcheri pond	-	107.0-122.0	136-147	-	104	8.0	4.9	-	Nagapattinham, Tanjore "
Eachangulam	0.8	107-122	122-148	3000	1062	7.8-8.6	5.2-7.4	nil	" " "
P.M.Nadar pond	0.8	238-553	312-466	1850	360	9.6	4.7-8.4	31.1	" " "
Aladikulam	1.2	140-220	41-96	600	96-116	8.1-8.7	0.6-4.4	112.2	Adirampatnam, " "
Chekkadikulam	1.5	186-378	98-124	1275	96-274	8.1-8.3	1.5-4.8	80.2	" " "
Pillaikulam	2.6	177.421	88-116	1350	268-272	8.1-8.6	0.8-4.6	86.2	" " "
Patraikulam	3.2	104	96	-	84	8.7	6.6	-	" " "

Table I (Cont'd)

1	2	3	4	5	6	7	8	9	10
E. Large irrigation tanks									
Odathurai tank	60	112.9-576.0	16-284	410-500	21.6-72.0	8.8	6.6	26.8-28.4	Coimbatore district
Ananthasagaram tank	45								
Tamaraikulam	6.7	162.0-293.0	122-134	800-1025	104-220.0	8.3-8.5	3.2-9.2	28.1-36.1	Tiruvannamalai, N.A.district
F. Other village ponds									
Pidarikulam	0.8	133-729	71	1810	90-224	7.5-8.1	1.1-3.7	7.8-8.0	Tiruvannamalai, Kumbakonam, Tanjore district
Ayikulam	0.4	171-223	90-144	380	22-30	7.5-8.8	0.9-12.8	43.4	-do-
Baburajapuram pond	0.4	201-207	126-201	320	46-198	7.5-7.6	2.7-3.6	32.1	-do-
Chettikulam	1.1	33.6-129	-	495	95-152	8.4-9.6	7.6-13.8	33.2	Kancheepuram, Chinglepat "
Tirumakulam	1.6	112.5-201	-	620	47-98	7.9-8.2	1.4-6.1	98.6	Madurai
Valvaiveesi Teppam	0.3	500	1750	1750	330-375	8.5	4.9	92.6	Madurai
Masinagudi tank	1.6	73.2-339	62-220	170-600	48.0	6.4-8.5	1.8-6.8	35.8-40.1	Nilgiri district
Vellaikulam, Arni	0.08	91.5-97.6	76-84	320	52-82	7.5-8.6	2.1-3.0	-	Arni, North Arcot district
Theerthankulam	1.2	54.9-176.8	188.270	625-3800	141-174	7.3-9.2	1.0-8.8	38.8	Tindivanam, South Arcot
Kumundankulam	0.6	45.8	72	385	69-82	8.8-9.1	0.8	92.2	Pudukkottai, Trichy district
Kilnainar Eri	0.5	30.5-400	74.92	-	88-110	7.15-9.2	0.0	-	-do-
Palanaiandi Oorani	0.5	156.0-180	100-138	320-1025	80-224	7.3-8.8	3.2-7.2	57.1	-do-
Servaroyankulam	0.4	278.0-308	134-184	2225	76-664	8.3	nil	2.6	-do-
Vairanachi Oorani	0.3	424	282	-	349	8.5		-	-do-
Rajakulam	0.8	159-358	60.84	330-760	80.144	7.1-9.6	0.0-20.4	12.0	-do-
Nathappallam	0.6	103.7	76	220	120	6.8-7.1	1.2	Tr	-do-
Melnainar Eri	1.6	85.4	280	2100	564	7.9	0.0	44.1	-do-
Holdsworth Park Pond	0.4	128.0	81	300	21.4	9.4	21.4	-	-do-
Vengappier Oothu	0.3	184.0	36.0	250	86.0	7.6	8.6	-	-do-
K.C.Kulam	0.6	119-250	170-216	820	116-250	7.9-8.2	1.4-6.1	50-8	Chinglepat district
Thimmarajakulam	0.6	149.5-157.5	-	630	50.0	7.3-8.4	3.3-8.2	45.4	-do-
Veppankulam	0.4	0.0-103.7	-	500	54-300	8.8-9.5	0.6	nil	-do-
Chettinad ponds	0.4	49.2-132.0	50-70	225-325	36-75	6.9-7.5	1.4-9.4	17.0-21.0	Chettinad, Ramnad district
Chettinad moat	0.8	48.0-91.2	76	175-241	64-83	6.6-7.9	6.5-8.8	30.3	-do-
Sandaimedu tank	0.3	183-224	87.96	425-470	60	7.7	2.1-11.0	24.0	Chengulam, North Arcot
Thenpadikulam	0.8	280.6	140	520	62	7.5	2.6	35.4	Sirkali, Tanjore

Table II

Stocking rates and fish yields in Madras ponds

Name of pond 1	Stocking rate No./ha 2	Species exploited (in the order of dominance) 3	Yield kg/ha/ year 4
1. Webster moat	95,000	Major carps, *Labeo* and *Cirrhina* spp. *Tilapia*, *Chanos*	5,486
2. Kallukatti tank	25,000	Entirely *Tilapia* (Small-sized)	3,481
3. West moat	16,500	Major carps, *Labeo* and *Cirrhina* spp. *Tilapia*, *Chanos*	3,353
4. Sengulam	6,230	*Labeo* and *Cirrhina* spp., *Catla*, *Chanos*, *Tilapia*	2,770
5. Anaiyadikulam	12,500	Major carps, *Labeo* and *Cirrhina*, *Chanos*	1,638
6. Tirukulam, Sirkali	16,750	Carps, *Catla*, mrigal, *Chanos*	1,810
7. Vellore fort moat	16,750	*Chanos*, carps, indigenous catfishes	1,580
8. Tirumkulam	8,750	Carps, *Tilapia*, *Catla*	1,516
9. Ayyankulam (Tanjore)	17,750	*Chanos*, carps, *Catla*	1,514
10. K.C.Kulam	3,000	*Tilapia*	1,483
11. Mariamman teppam	2,100	*Tilapia*	1,473
12. Ayikulam	15,000	*Labeo* and *Cirrhina* spp., murrels *Chanos*, *Catla*, mrigal	1,420
13. Pidarikulam	11,000	Major carps, *Labeo* and *Cirrhina*, *Chanos*	1,420
14. Ayyankulam (Tiruvannamalai)	13,500	*Chanos*, carps, *Catla*, *Tilapia*	1,395
15. Vairanachi oorani	8,500	*Tilapia*	1,334
16. Sandaimedu tank	-	*Chanos*, carps, *Tilapia*	1,309
17. Kilnainar eri '	22,500	*Tilapia* mostly	1,189
18. Servaroyankulam	13,000	-do-	1,148
19. Palaniandi oorani	12,000	-do-	1,126
20. Rettaikulam	1,325	-do-	1,020
21. Chinglepat fort moat	10,000	Carps, *Chanos*, *Tilapia*, murrels	888
22. Baburajapuram tank	7,500	Carps, *Chanos*	885
23. Kudundankulam	17,500	mainly *Tilapia*	845
24. Quarry pool I	13,500	*Tilapia*, *Chanos*, carps	797
25. Pattraikulam	3,250	*Catla*, *Labeo*, *Cirrhina*, *Chanos*	708
26. Pallavankulam	5,000	*Catla*, carps	689
27. Vellaikulam, Arni	9,450	*Tilapia*	685
28. Melnainar eri	4,700	*Tilapia*	651

Table II (Cont'd)

1	2	3	4
29. Theerthankulam	12,000	*Tilapia* mainly, carps and *Chanos*	649
30. Thimmarajakulam	2,500	*Tilapia* mainly, carps and *Chanos*	599
31. Aladikulam	5,000	*Labeo* and *Cirrhina* spp, Catla	578
32. Chettikulam	8,750	*Tilapia*, carps	540
33. Kachangulam	5,140	*Catla*, *Labeo*, mrigal, *Cirrhina cirrhosa*	530
34. Quarry pool II	7,500	*Tilapia* mainly, *Labeo* and *Cirrhina*	489
35. P. M. Nadar tank	3,730	*Catla*, *Labeo*, *Cirrhina cirrhosa*	468
36. Holdsworth park pond	2,750	*Tilapia*	470
37. Thenpadikulam	10,500	*Catla*, carps, *Chanos*	457
38. Chettinad ponds	11,000	Carps, *Tilapia*	485
39. Vengappier oothu	23,750	*Tilapia* mainly	484
40. Valaiveesiteppam	7,250	*Tilapia*	461
41. Masinagudi tank	550	*Cyprinus carpio* only	397
42. Periakulam	8,000	*Tilapia* mainly	347
43. Chekkadikulam	1,125	Carps, *Catla*, *Tilapia*	336
44. Sarvatheertham	10,500	*Tilapia*, *Chanos*, carps	321
45. Veppankulam	11,000	*Tilapia* mainly	328
46. Tamaraikulam	3,750	*Tilapia*, murrels, carps	311
47. Pillaikulam	1,875	Carps, *Catla*	279
48. Arni Fort Moat	1,875	*Tilapia*, carps, *Chanos*	269
49. Teppakulam, Sivaganga	3,000	*Catla*, *Labeo* and *Cirrhina*, *Tilapia* *Chanos*, murrels	243
50. Quarry pool III	7,500	*Tilapia* mainly, *Chanos*	240
51. Rajakulam	6,000	*Tilapia* mainly	175
52. Nathappallam	2,250	*Tilapia* mainly	150
53. Vellaikulam, Kancheepuram	1,750	Carps	100
54. Odathurai tank	1,250	*Tilapia*, *Cirrhina* and *Labeo* spp	67
55. Ananthasagaram tank	1,750	*Tilapia* mainly	56
56. Chettinad Moat	1,000	Carps, *Tilapia*	45

Table III

Fish production in the ponds and certain chemical parameters

Name of pond 1	Bicarbonate HCO_3 ppm 2	Hardness $(CaCO_3)$ ppm 3	Calcium ppm 4	Electrical conductivity ppm 5
I(a) 3,000 kg/ha				
Webster moat	102-220	114-170	48-54	695
West moat	92-183	104	52.0	490
Kallukkatti tank	101-183	102-154	26.2-35.0	475
(b) 1,000 kg/ha				
Sengulam	116-281	144-170	19.6-46.1	890
Tirukulam, Sirkali	189	92	4.7	380
Amaiyadikulam	378-607	290-360	21.4	1950
Vallore fort moat	256	166-490	48-54	1125-2500
Tirumakulam	113-201	-	98-06	620
Ayyankulam, Tanjore	220	104	52.1	490
K.O.Kulam	119-250	170-216	50.8	820
Mariamman teppam	156-451	182-200	61.1	2650
Ayikulam	171-223	90-144	43.4	380
Pidarikulam	133-729	71	78.8	1810
Ayyangulam (T.V.malai)	217-226	66-300	43.8	800-1350
Vairanachi oorani	424	282	-	-
Sandaimedu tank	189-224	87-97	24.0	425-470
Kilnainar eri	400	74-92	-	-
Servaroyankulam	278-308	134-184	nil	2225
Palaniandi oorani	184-186	40-79	135.2	290-1675
II. 500-999 kg/ha				
Chinglepat fort moat	152.5-432	113-550	21-34	630-1150
Baburajapuram tank	201-207	126-301	32	320
Kumundankulam	46	72	92.2	385
Quarry pool I	167.8	70	44.1	2125
Pattraikulam	104	96	-	-
Pallavankulam	98-176	50-90	95-2	170-375
Vellaikulam, Arni	91.5	76	-	320
Melnainar eri	85.4	280	44.1	2100
Theerthankulam	177	188-207	39	625-3800
Thimmarajakulam	150-157	-	45.4	630

Table III (Cont'd)

1	2	3	4	5
Aladikulam	140-219	41-96	112-2	600
Chettikulam	129	-	33.2	495
Eachangulam	107-122	122-148	nil	3000
III. 100 to 499 kg/ha				
Quarry pool II	326	34	34.1	3000
Chettinad ponds	49.2-132	50-70	17-21	225-325
Vengappier oothu	184	36	-	250
Holdsworth park pond	128	81	-	300
P.M. Nadar tank	238-553	213-446	31.1	1850
Valaiveesi teppam	500	-	92.6	1750
Thenpadikulam	281	140	35.4	520
Masinagudi tank	73.2	62-220	35.4	520
Periakulam	76-242	222	69.8	3000
Chekkadikulam	186-378	98-124	80.2	1275
Veppankulam	0.0-103.7(OH')	-	nil	500
Sarvatheerthan	98.5-214	-	33.6	460
Tamaraikulam	162-293	122-134	28.1-36.1	800-1025
Pillaikulam	177-241	88-116	86.2	1350
Arni fort moat	107-256	150-228	25.5	610-1900
Teppakulam (Sivaganga)	104-201	80	34.1	900
Quarry pool III	219.6	134	34.1	725
Rajakulam	0.0-358(OH')	60-84	12.0	330-760
Nathapallam	103.7	76	Tr	220
Vellaikulam (Kancheepuram)	180-247	-	65.3	805
IV. Less than 100 kg/ha				
Odathurai tank	113-576	284-166	-	410-500
Ananthazagaram tank	262.3	-	31.6	525
Chettinad moat	48.92	76	30.3	175-241

Table IV

Soil nutrients in the fish ponds

1	Phosphate (available) ppm 2	Calcium ppm 3	Magnesium ppm 4	NH_3 ppm 5	Organic nic matter% 6	pH 7
Webster moat	1-2.5	10-20	2-6	0-25	1.9-3.1	7.2-8.0
Kallukati tank	0.5	40	6	10	8.48	8.0
West moat	0.25	100	-	10	11.3	8.0
Seagulam	Tr	20	2	nil		7.4
Anaiyadikulam	1.0	20-150	6.8	2-15	10.8	7.2-8.0
Vellore fort moat	0.5-1.0	100-200	6	0-10	5.8	7.0-8.0
Tirumakulam	0.5-2.5	40-150	4.8	2	0.5	8.0
Tirukulam (Sirkali)	0.75	40	6	15		7.0
Ayyankulam (Tanjore)	0.25	150	nil	10	8.0	7.5
K.C.Kulam	1.0-2.0	20-100	4	nil-25		7.5-8.0
Mariamman tappam	0.5-1.0	40-150	6-8	2-10	0.4	8.0
Ayikulam	0.5-2.5	20-40	Tr-8	2-10	7.8	7.4-8.0
Pidarikulam	0.75-0.5	40-100	4	25-Tr		7.8
Ayyangulam (Turuvannamalai)	0.5	20	0.0-6	2-10	0.6	7.2-8.0
Sandaimeda tank	1.0	40	4	2		7.8
Servaroyankulam	1.0	200	6	2		8.0
Palaniaadi oorani	0.5	200	4	10		8.0
Rattaikulam	0.5	20	4	2		8.0
Chinglepat fort moat	0.5-2.0	20	4-6	25-2		8.0
Baburajapuram tank	0.5-1.0	20-40	Tr-6	Tr	7.8	7.0-7.5
Quarry pool No.I	0.5-1.0	100-150	2-6	Tr-2		8.0
Pallavankulam	0.5	20	4	2		8.0
Melnainar eri	0.5	150	6	2		8.0
Theerthankulam	0.5-1.0	20-200	6-10	10-25	15-5	7.6-8.0
Thimmarajakulam	0.5	100-200	2.12	0.200		7.5-8.0
Aladikulam	Tr	150	6	10		7.2
Chettikulam	0.5-2.5	20-100	4.12	2-25		8.0
Eachangulam	0.5	20	4	15		7.2
Quarry pool No.II	0.5	100-150	6-8	Tr-10		8.0
P.M.Nadar tank	0.5	2.0	4	10		6.8

Table IV (Cont'd)

1	2	3	4	5	6	7
Thenpadikulam	0.75	20	4	25		7.0
Chettinad pond	0.5-0.75	20-100	2.4	Tr-25	8.04	6.7-7.0
Valaiveesi teppam	0.5-1.0	40-150	6-8	2-10	0-4	8.0
Masinagudi tank	0.5-1.0	20	1-6	0-10	12.1-19.3	6.6-7.5
Chekkadikulam	Tr	40	6	nil		7.6
Veppankulam	0.5	Tr-5	4	2-10		7.5-8.0
Tamaraikulam	0.5	10-40	6	2		7.4-8.0
Pillaikulam	Tr	20	2	nil		7.2
Arni fort moat	0.75	100	6	10		8.0
Quarry pool No.III	0.5	150	6	2		8.0
Rajakulam	0.5	100	4	25		7.2
Nathapallam	0.5			2		6.8
Vellaikulam (Kancheepuram)	0.5	20-80	4-6	2		8.0
Odathurai tank	0.5	20	8	0-10	0.25	6.8-8.0
Ananthasagaram tank	0.5	20	6	0-10	1.01	6.8-8.0
Chettinad moat	0.5-0.75	20-100	2.6	nil		6.0-7.0

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II/E-10

A SURVEY OF THE ALGAL PASTURE SOILS OF MILKFISH PONDS IN TAIWAN

by

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A SURVEY OF THE ALGAL PASTURE SOILS OF MILKFISH PONDS IN TAIWAN

Abstract

The total area of milkfish ponds in Taiwan at present is about 18,100 ha. The average yield of pasture algae mainly consisting of filamentous blue-greens and diatoms during the fish rearing season is estimated to be approximately 25,000 kg/ha which can maintain an average milkfish production of about 2,000 kg/ha.

The optimum elevation of the algal pasture soil is from the mean sea-level to an altitude of 0.45 m. Elevations of 0.6 m or more are also suitable for algal pasture provided that the water for these ponds can be supplied by pumping. However, pond bottoms below the mean sea-level (0.2 m or more) are unsuited because of seepage which may destroy algal beds.

The algal pasture soils of milkfish ponds consist of alluvial tidal flats of recent origin. Silty loam and loam soils are the most favourable for growing pasture algae.

The pH values of algal pasture soils generally range from 8.0 to 9.5 which is considered to be optimum for the growth of these algae. This alkaline reaction is predominantly due to the presence of sodium chloride and sodium sulphate.

The organic matter content of the soils ranges from 0.27 to 5.79, and it has been observed that higher organic matter contents contribute to better growth of pasture algae.

The C/N ratio of organic matter in the algal beds is relatively wide, with a range of 21.1 to 25.1, the total nitrogen content ranges from 0.07 to 0.24 percent, the NH_3-N and NO_3-N contents are mostly above 25 and 15 ppm respectively and the available phosphorus and potassium contents are generally above 45 ppm and 400 ppm respectively.

The available Ca and Mg contents range from 700 to 1,200 ppm and from 300 to 600 ppm respectively and chlorine content generally from 3,000 to 6,000 ppm.

ETUDE DES SOLS A PATURAGE ALGAL DANS LES ETANGS DE CHANOS A TAIWAN

Résumé

La superficie totale des étangs consacrés à l'élevage des chanos à Taïwan représente actuellement environ 18 100 ha. La production moyenne des algues de pâturage, consistant principalement en algues bleues filamenteuses et en diatomées, au cours de la période de croissance du poisson est estimée à environ 25 000 kg/ha, quantité suffisante pour assurer une production moyenne de chanos d'environ 2 000 kg/ha.

L'élévation optimum des sols convenant aux algues de pâturage est 0,45 m au-dessus du niveau moyen de la mer. Les élévations de 0,6 m ou davantage conviennent également à condition que l'alimentation en eau puisse être assurée par pompage. Toutefois, lorsque le fond des étangs se trouve au-dessous du niveau moyen de la mer (0,2 m ou davantage), ces emplacements ne conviennent pas à cause des infiltrations qui risquent de détruire les lits d'algues.

Les sols à pâturage algal des étangs à chanos sont des plages alluviales de formation récente. Les sols argileux et argilo-limoneux sont ceux qui conviennent le mieux à la croissance des algues de pâturage.

La valeur du pH des sols à pâturage algal se situe en général entre 8,0 et 9,5, ce qui paraît être l'optimum pour la croissance de ces algues. Cette réaction alcaline est essentiellement due à la présence de chlorure de sodium et de sulfate de sodium.

La teneur en matière organique des sols varie entre 0,27 et 5,79, et il a été constaté qu'une teneur élevée en matière organique contribue à favoriser la croissance des algues de pâturage.

Le rapport C/N de la matière organique des lits d'algues peut aller de 21.1 à 25.1, la teneur total en azote se situe entre 0,07 et 0,24 pour cent, la teneur en NH_3 - N et NO_3 - N est en général au-dessus de 25 et 15 ppm respectivement, et la teneur en phosphore et en potassium utilisables dépasse généralement 45 ppm et 40 ppm respectivement.

La teneur en Ca et en Mg utilisables va de 700 à 1 200 ppm et de 300 à 600 ppm respectivement et la teneur en chlore oscille généralement entre 3 000 et 6 000 ppm.

ESTUDIO DE LOS SUELOS DE PASTOS DE ALGAS EN LOS ESTANQUES DE SABALOTE EN TAIWAN

Extracto

La superficie total de los estanques dedicados en Taiwan a la cría del sabalote (Chanos chanos) es actualmente de unas 18.100 Ha. El rendimiento medio de las algas de pasto constituídas principalmente por algas filamentosas verde-azules y diatomeas durante la temporada de cría del pez se estima que es aproximadamente de 25.000 Kg/Ha, lo que puede mantener una producción media de sabalote de unos 2.000 Kg/Ha.

La elevación óptima del suelo de pasto de algas se encuentra entre el nivel medio del mar y una altitud de 0,45 m. También son apropiadas para los pastos de algas las elevaciones de 0,6 m o más, a condición de que el agua para tales estanques pueda suministrarse mediante bombas. Sin embargo, los fondos de estanques situados por debajo del nivel del mar (0,2 m o más) son inadecuados, a causa de las filtraciones que pueden destruir los lechos de algas.

Los suelos de pastos de algas en los estanques de sabalote están constituídos por tierras aluviales de origen reciente, bañadas por la marea. Los suelos francos y francolinos son los más favorables para la producción de algas para pasto.

Los valores del pH en los suelos de algas de pasto, varía generalmente entre 8,0 y 9,5 lo que se considera óptimo para el desarrollo de estas algas. Esta reacción alcalina se debe principalmente a la presencia de cloruro de sodio y de sulfato sódico.

El contenido de materia orgánica de los suelos varía de 0,27 a 5,79, y se ha observado que cuanto mayor es el contenido de materia orgánica tanto mejor se desarrollan las algas de pasto.

La relación C/N de la materia orgánica en los lechos de algas es relativamente amplia, oscilando entre 21:1 y 25:1; el contenido de nitrógeno total varía de 0,07 a 0,24 por ciento; los de NH_3-N y NO_3-N casi siempre son superiores a 25 y 15 ppm, respectivamente, y los contenidos de fósforo y potasio disponibles normalmente son superiores a 45 ppm, respectivamente.

El contenido de Ca y Mg disponibles oscila entre 700 y 1.200 ppm y entre 300 y 600 ppm, respectivamente, y el de cloro generalmente entre 3.000 y 6.000 ppm.

1 THE ROLE OF BOTTOM SOILS IN PRODUCTIVITY OF MILKFISH PONDS

The culture of milkfish, Chanos chanos (Forskal) in brackish-water ponds is intrinsically similar to cattle and sheep husbandry in which good growth of pasture is the foundation for efficient production. Pasture algae - mainly the filamentous blue-greens and the diatoms - supply the most desirable and economical food for milkfish during the growing season, and unless good algal pastures are maintained on the pond bottoms during a large part of the fish rearing season, the yields of milkfish will be low and the profits much reduced. Moreover, a luxuriant growth of these pasture algae can crowd out undesirable groups of algae, and possibly other harmful organisms, from the ponds. As the production of milkfish from brackish-water ponds is directly proportional to the growth of the algal pasture, the management of milkfish ponds lays strong emphasis on techniques for regulating the environmental conditions to favour the growth of these groups of algae, and on a constant supply of the necessary plant nutrients for their growth by fertilization and management of the bottom soils.

In fresh-water ponds soils are mainly important as a nutrient storehouse, but in milkfish ponds they also act as a "bed" for the establishment of the algal pasture and the fertility of the bottom soils of milkfish ponds governs the algal pasture production.

2 AREA AND DISTRIBUTION

The total area of milkfish ponds in Taiwan at the end of 1964 amounted to 18,100 ha (including 1,600 ha which are under construction). These ponds are distributed on the tidal lands along the rivers and creeks. The west coast of the Chai-Nan Plain is the centre of this industry. Here more than 80 percent of the total area of this type of pond is distributed, and the rest are scattered southward of the coast.

3 CLIMATE

The Chai-Nan Plain is the boundary between the tropic and temperate zones as the Tropic of Cancer crosses this plain. The western inland edge of this plain stretches about 120 kilometers along the coast. The annual water temperature of the milkfish ponds in this region ranges from 8° to 33°C. The temperature during the fish rearing season from the early part of April to the middle of November is from 25° to 33°C. Both the pasture algae and milkfish prefer a relatively high water temperature, above 23° to 25°C. Milkfish die from cold when the water temperature falls to about 9° to 11°C. The annual rainfall in this region is about 2,159 mm and the annual evaporation is about 1,454 mm (1951-1960). Wet and dry seasons in this region are very pronounced; it is wet from May to September and dry during the rest of the year. The pasture algae and milkfish grow well from the latter part of May to the end of August when the pond water salinity ranges from 10 to 30 ppt due to the dilution by rain. The salinity is about 50 ppt or more before the rainy season, and less than 5 ppt at the end of the rainy season which often destroys the growth of pasture algae. The water flowing out of the ponds due to heavy rain causes the loss of plant nutrients and the deterioration of soil fertility. This is especially true during the latter part of the rainy season when the salinity of the pond water is low and when the topmost layer of bottom soil is not well covered with algal pasture.

4 ELEVATION OF POND BOTTOM

The elevation of the bottoms of milkfish ponds in Taiwan ranges from -0.5 to + 1.2 m from the datum plane of the mean sea level. Since the mean water levels of neap and spring tides in this region are respectively 0.69 m and 0.85 m, the optimum range for the pond bottom elevation is approximately at ±0.0 to +0.45 m. For ponds with bottoms at +0.6 m or more, supplemental filling of the ponds with water by pumping is necessary. However, the ponds located on the lower tidal lands, more than 0.2 m below the mean sea-level, are difficult to manage because the seepage water causes changes in the physical conditions of the pond bottom making the topmost layer of the soil unfavourable for the growth of algal pasture.

5 KINDS OF ALGAE AND THEIR YIELD

The algal pasture in milkfish ponds consist of two main groups of microscopic algae, the filamentous blue-green Cyanophyceae and the diatoms, Bacillariophyceae. The major genera of Cyanophyceae are Oscillatoria, Lyngbya, Phormidium, Spirulina, Microcoleus and possibly other genera of the order Oscillatoriales; the major genera of Bacillariophyceae are Navicula, Pleurosigma, Amphiprora, Mastogloia, Stauroneis, Amphora, Nitzschia and various unidentified genera of the order Centrales.

It is estimated that the total amount of pasture algae grazed by the milkfish during the fish rearing season from April to October approximates 25,000 kg per ha.

6 TILLAGE AND SOIL MANAGEMENT

Milkfish ponds in Taiwan are filled with water from April to October to a depth ranging from 25 to 50 cm adjusted in accordance with the growing conditions of the algal pasture and with the amount of the fish stocked in the ponds. The pasture algae generally thrive better in relatively shallow water, whereas the fish need a greater volume of water. During the fallow period, from November to March, alternate drying and wetting of the bottom soils with sea water is practised to increase the supply of salt and other algal nutrients in the soil, and to ameliorate the soil conditions. Detailed accounts of this practice are given by Chen (1952) and Tang and Chen (1957).

The most common fertilizer applied in the milkfish ponds is rice bran. Compost manures are also used, but the area of ponds where this kind of fertilizer is used is very limited. Rice bran is also used as supplementary feed during the rainy days of the latter part of the fish rearing season. Actually a large portion of the rice bran applied in this case is accumulated on the pond bottoms and acts as fertilizer for algal growth. Chemical fertilizers such as ammonium sulphate, urea and phosphates, have recently been used but only on a small scale. According to general practice, the N-P-K requirement of the soils to maintain an average level of algal pasture production during a fish rearing season is about 60 kg/ha nitrogen, 45 kg/ha P_2O_5, and 25 kg/ha K_2O. Grasses and sedges grown on the pond dykes, and rice straws after they had been used for thatching the wind-breaks of the wintering ponds, are scattered on the pond bottoms at the end of the fish rearing season every year. This is also one of the important means for the maintenance of soil fertility.

7 GEOLOGY

The milkfish ponds of Taiwan are distributed on the recent alluvial deposits on the tidal flats. The parent materials of these deposits are derived from calcarious slates and crystalline schists that have been transported from the central mountain ranges of the island. The surface run-off and streams running down from the mountains are always so heavily loaded with these particles that they are muddy. When the creeks and streams reach the esturine areas, the flow slows down and the muddy particles are deposited causing these areas to become gradually higher. The formation and expansion of this alluvial tidal flat results in constant flooding. Because the alluvium is pushed westward to the sea, the older ponds gradually become farther from the sea and it becomes more difficult for them to obtain a supply of sea water. Consequently, these ponds are gradually converted into farm land by desalinizing with fresh water. This process of land reclamation is practised in many of the milkfish pond areas along the west coast of Taiwan.

8 SOIL TESTS

Fertility tests for the soil samples were made for the surface soil only, as it was considered that the subsoil of the pond bottom has less effect upon the growth of pasture algae because algae are rootless and also because the bottom soils of milkfish ponds have never been ploughed in accordance with the traditional method of cultivation. In sampling the surface soil, the method that is customarily used by agronomists for sampling pasture lands was employed. In this method, dead and living vegetation of the surface were excluded in the samples.

8.1 Soil texture

Mechanical analyses of the soil samples were made by the pipette method. Six textural classes (Atterberg scale) were found from the algal pasture soils, i.e. sand, loamy sand, sandy loam, loam, silty loam and silt. The area of each textural class of the algal pasture soils in Taiwan was estimated (Table I). The average compositions of sand, silt and clay of these textural classes are graphically shown in Fig. 1. Of these textural classes, silty loam is the most favourable one for the growth of the pasture algae. The majority of the most productive ponds are distributed in regions with this type of soil. Loam soil is also suitable for these algae because of its balanced composition of sand, silt and clay. Algal pastures also grow well on silt and sandy loam soils provided that the soil fertility of these textural classes is well managed and maintained. The soils of sand and loamy sand texture do not grow good quantities of pasture algae because of their light texture and low content of clay and fine silt, which constitute the most active portions of the bottom soils for the growth of algal pasture by formation of soil colloids.

Table I

Textural classes of the algal pasture soils of milkfish ponds

Textural class	Sand	Loamy sand	Sandy loam	Loam	Silty loam	Silt
Number of samples	21	4	74	12	189	18
Estimated area ha	1,180	240	4,200	730	10,700	1,050

Experiments on the growth of pasture algae on the different types of soil represented by the bottom soils of milkfish ponds in Taiwan were also conducted in a greenhouse under controlled environmental conditions. The results of these experiments are summarized in Table II. It can be seen from this table that the quantities of algae produced from the respective classes of soil texture coincide with the results observed from the field.

Table II

The growth of pasture algae in relation to the textural classes of the bottom soils of milkfish ponds 1/

(The quantities of algae produced from the soils of respective classes of texture are indicated by the loss of weight on ignition from the algal pasture samples)

Soil textural class	Wet weight of algal pasture (g/m^2)	Dry weight of algal pasture (g/m^2)	Weight of the residues after ignition (g/m^2)	Loss of weight on ignition (g/m^2)
Sand	2,312.70	393.15	309.47	83.68
Loamy sand	2,667.10	453.42	366.31	87.10
Sandy loam	2,993.80	508.94	394.21	114.73
Loam	3,123.80	531.05	360.26	170.79
Silty loam	2,843.70	483.42	307.36	176.05
Silt	2,577.40	438.15	325.26	112.89

1/ This trial was made with a series of 42 glass bowls with a capacity of π45 x 30 cm each; each class of soil texture was tested with 7 duplicates of 3 repeats in a greenhouse in identical environments.

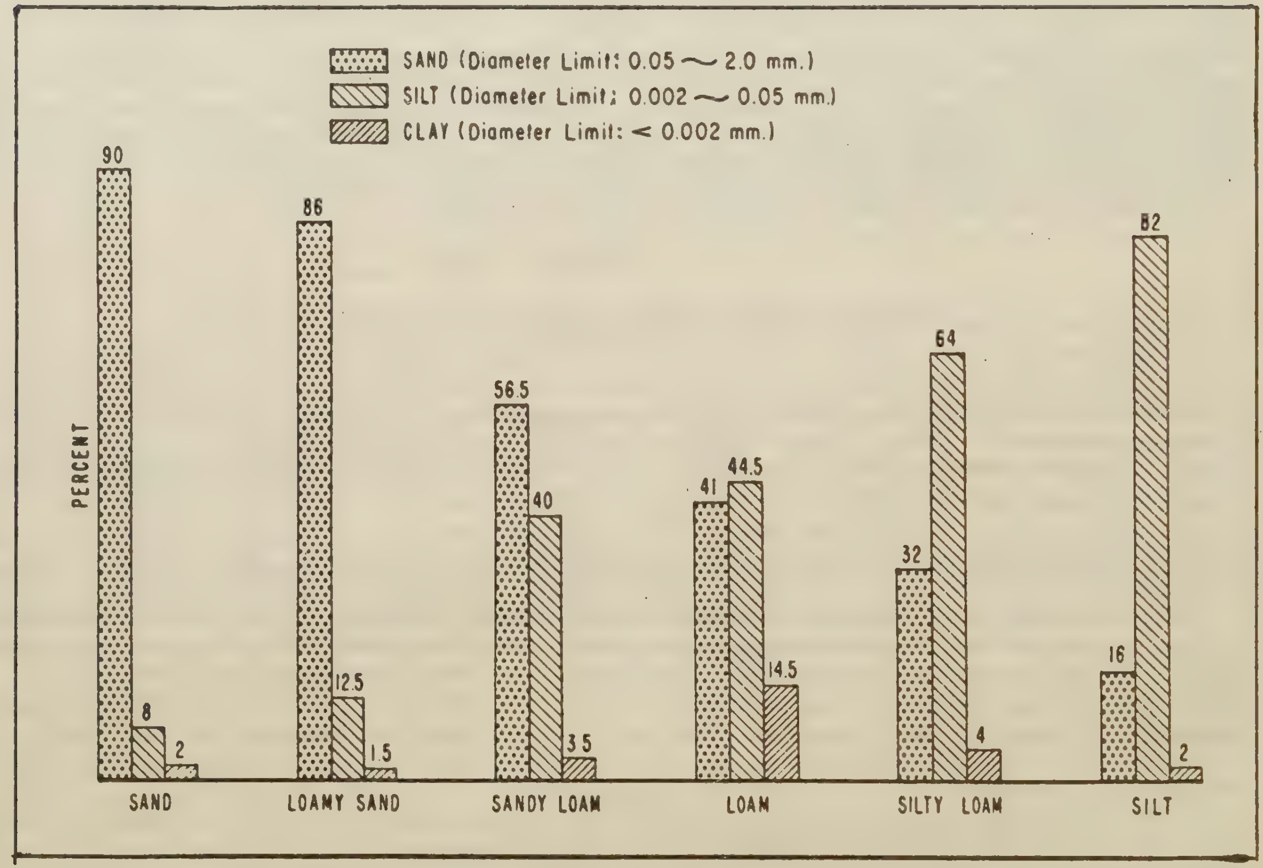

Fig. 1- Graphic representation of the mechanical analysis of the representative classes of algal soil textures

8.2 Soil reaction

The pH values determined by the glass electrode method, ranged from 7.5 to 9.7 for these soil samples. The pH fluctuates greatly with the season, being highest at the end of the dry season, and lowest at the end of the rainy season (Table III). This alkaline reaction is mainly due to the presence of sodium chloride and sodium sulphate. But there were exceptional cases where an acid reaction, with a pH range from 5.5 to 6.8 was found in some of the soil samples from the ponds where the pond bottom is below the mean sea level. This acid reaction is probably due to the decomposition of organic matter under anaerobic conditions. Generally speaking, the alkaline soils rich in sodium are favourable for the growth of these algae.

Table III

The pH values of the algal pasture soils of milkfish ponds

Range of pH value	7.5-8.0	8.1-8.5	8.6-9.0	9.1-9.5	9.6-10
Number of samples examined during dry season	-	21	63	123	96
Number of samples examined during wet season	32	127	102	57	-

8.3 Soil organic matter

8.3.1 Organic matter in the surface soil

The organic matter content of the soil samples was determined by Graham's wet combustion colorimetric method with a photoelectric colorimeter. The results of this analysis are given in Table IV. The organic matter in the surface soil in relation to the productivity of milkfish ponds based on this survey is shown in Table V. Since the growth of these groups of algae, particularly the blue-greens, requires much organic matter in the soil, pond bottoms which are rich in organic matter are indicative of high productivity.

Table IV

Organic matter in the algal pasture soils of milkfish ponds

Organic matter (percent)	< 1.5 (low)	1.6 - 3.5 (medium)	> 3.6 (high)
Number of samples	120	159	51
Estimated area ha	6,400 1/	8,700	3,000

1/ Including an area of 1,600 ha which is under construction

Table V

Organic matter content of the algal pasture soils in relation to the productivity of milkfish ponds in different regions

Region	Number of samples	Organic matter content (percent)	Annual yield of algae (kg/ha)	Annual yield of fish (kg/ha) 1/
Tseng wen 2/	26	0.39	-	-
Kaou ho Tai shi Chi ku Hsien wen	29	1.23	15,000	1,200
Pu dai Shen wen Ih chu Shuang chun	75	2.41	18,750	1,500
Pei men Chi ku Tu cheng An nan Yung an	158	3.27	25,000	2,000
An ping Tsu kuan Lin pein Ni to	61	4.17	28,250	2,500

1/ Based on the data obtained from an investigation under the project "The Economic Statistics of Fish Culture Industry" in 1964

2/ Ponds are under construction

Table VI

Chemical composition of organic matter contained in the algal beds of the bottom soils of milkfish ponds in different regions

Region	Number of samples	Organic matter (on the basis of dry soil samples)			
		Loss on ignition (percent)	Organic carbon x 1.72 (percent)	Total Nitrogen (percent)	C/N ratio
Pu dai Shen wen	26	7.44	9.59	0.26	21.42
Chi ku Tu cheng An nan Yung an	74	12.57	16.75	0.41	23.75
An ping Tzu kuan	23	26.76	31.37	0.76	24.98

8.3.2. Organic matter in the algal bed

The top-most layer of the pond bottom is termed "algal bed" as it comprises a large portion of organic soil colloids which are considered to be the most active portions of the soils for production of pasture algae. In sampling the algal bed for chemical analysis of the organic matter, the top-soil to a depth of 10 cm and the mat of the algae pasture which had been destroyed by desiccation were included.

The organic matter content of the algal beds was measured by the loss of weight on ignition, and by the organic carbon and total nitrogen content. The determination of organic carbon was made by the modified Schollenberger's method and the total nitrogen by the usual Kjeldahl method.

The chemical composition of the organic matter in the algal beds of the bottom soils in different regions indicated in Table V are shown in Table VI. These tables show that the most productive ponds are usually those having a higher content of organic matter in the algal bed. In other words, the better algal beds are usually established on those bottom soils rich in organic matter. The higher C/N ratio indicated in the organic matter of the algal beds is due mainly to the fact that the decomposition of algal gel, extracted from the residues of the pasture algae by desiccation, is still in process.

8.4 Nitrogen

Total nitrogen, ammonia nitrogen and nitrate nitrogen contents of the surface soils were examined by the usual chemical methods. Total nitrogen is richer in the bottom soils where the soil texture is relatively heavier, and where good management has retained the soil fertility for a long period of time.

The NH_3-N content in the surface soil of the pond bottoms generally range from 25 to 45 ppm. The differences were too small to indicate any direct relationship between the amount of NH_3-N and productivity. The range of NO_3-N content in the soils of the pond bottom was even smaller than the NH_3-N, generally between 15 to 30 ppm.

The total nitrogen in the soils is, of course, directly proportional to the amount of organic matter. Soils of higher total nitrogen content undoubtedly produce higher yields of pasture algae. This fact has also been proved both by culture of these algae in greenhouse under controlled conditions, and by fertilization field trials.

Table VII

Total nitrogen in the algal pasture soils of milkfish ponds

Total nitrogen (percent)	$<$ 0.10 (Very low)	0.11-0.15 (low)	0.16-0.20 (medium)	$>$ 0.21 (high)
Number of samples	39	84	174	38

8.5 Available phosphorus

The content of available phosphorus in the samples was determined by Bray's method and the results obtained are indicated in Table VIII. Generally, the algal pasture soils are rich in available phosphorus and contain an average of 42 ppm for the whole sample. As available phosphorus promotes the growth of pasture algae, the application of either organic or inorganic phosphate to the bottom soils, alone or in combination with nitrogen fertilizers, improved the growth of pasture algae both in the greenhouse and in field tests. Therefore, the application of phosphate to the algal pasture soil is deemed very necessary.

Table VIII

The available phosphorus in the algal pasture soils
of milkfish ponds

Available phosphorus (ppm)	< 35 (low)	36-45 (medium)	> 46 (high)
Number of samples	74	102	166

8.6 Available potassium

Available potassium in the soil samples was determined by Peech's cobalt nitrate turbidimetric method. The range of available potassium content of the algal pasture soil is from 326 to 709 ppm. The wide range of available potassium content is due mainly to the accumulation of potassium chloride from sea water by periodical evaporation. It is doubtful whether the algal pasture soil needs any application of potash since the results from experiments conducted in both greenhouse and field indicate that the algal pasture soil shows no response to potash from both organic and inorganic sources.

Table IX

Available potassium in the algal pasture soils of milkfish ponds

Available K (ppm)	< 350 (low)	350-500 (medium)	> 500 (high)
Number of samples	36	148	159

8.7 Available calcium and magnesium

The available Ca and Mg were determined by Peech's soap solution and titan yellow colorimetric methods respectively (Table X). As there is no soluble carbonate in the algal pasture soil, the Ca and Mg may not change the alkaline reaction of the soil samples.

Table X

Available Ca and Mg in the algal pasture soils of
milkfish ponds

Available Ca (ppm)	< 700 (low)	700-1,200 (medium)	> 1,200 (high)
Number of samples	50	134	151
Available Mg (ppm)	< 300 (low)	300-600 (medium)	> 600 (high)
Number of samples	46	118	168

8.8 Chloride content

The chloride content was determined by use of the usual chemical methods and the results are indicated in Table XI. The high chloride content of the algal pasture soil is of course derived from sodium and magnesium. As the pasture algae prefer to grow in water of a certain range of salinity, an increase of chlorides in the soils, by evaporation of sea water during the fallow season, may be necessary.

Table XI

Chloride content of the algal pasture soils of milkfish ponds

Chloride (ppm)	< 2,000 (low)	2,000-5,000 (medium)	> 5,000 (high)
Number of samples	32	144	163

9 REFERENCES

Chen, Tung-Pai, Milkfish culture in Taiwan. Fish.Ser.Chin.-Amer.Comm.rur.Reconstr., 1952 (1):17 p.

Tang, Yun-An and T.P. Chen, The use of chemical fertilizers in the milkfish ponds of 1957 Taiwan. Fish.Ser.Chin.-Amer.Comm.rur.Reconstr., (3):19 p.

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II/E-11

INCREASE OF PRODUCTION IN FRESH-WATER FISH PONDS BY THE USE OF INORGANIC FERTILIZERS

by

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Abstract

The management of eight ponds with an area of 39.6 hectares in a fish farm in Taiwan suffered financial loss for seven consecutive years. A turn from apparently unrecoverable loss to profit was achieved by the use of superphosphate fertilizers in 1965. Heavy stocking of the plankton-feeding silver carp and bighead, in combination with other favourable conditions contributed to the striking results obtained. The experiment showed that although a heavy dose of 180 kg/ha of P_2O_5 gives a fish yield high enough for profit, the most efficient and economical dose is 40 kg/ha, as fish yield is not proportional to the dosage of

P_2O_5. The experiment also revealed that the higher the productivity of a pond, the less P_2O_5 fertilization is needed; perhaps 20 kg/ha may be adequate for maintaining a high level of production. Though the use of complete N-P-K fertilizers entails more expense than the use of superphosphate alone, it does not give a much higher yield. The effect of inorganic fertilizers is limited in ponds where productivity due to mineral nutrients has already reached the maximum.

AUGMENTATION DE LA PRODUCTION DANS LES ETANGS DE PISCICULTURE D'EAU DOUCE PAR L'EMPLOI D'ENGRAIS INORGANIQUES

Résumé

Dans une exploitation piscicole de Taïwan, la gestion de huit étangs d'une superficie de 39,6 hectares a été déficitaire pendant sept années consécutives. La situation, qui paraissait irrémédiablement compromise, a été rétablie en 1965 et des profits ont été réalisés grâce à l'emploi de superphosphates. Une densité élevée d'empoissonnement en silver carp et big head carp planctonophages, jointe à d'autres conditions favorables, à contribué aux résultats remarquables que l'on a pu obtenir. L'expérience a prouvé que si une forte dose de P_2O_5 (180 kg/ha) assure une production de poisson suffisamment élevée pour que l'entreprise soit profitable, la dose la plus efficace et la plus économique est de 40 kg/ha, car le rendement n'est pas proportionnel à la quantité de P_2O_5 utilisée. L'expérience a également révélé que plus un étang était productif moins il fallait employer de P_2O_5; il n'est pas exclu qu'une dose de 20 kg/ha puisse suffire pour maintenir un haut niveau de production. Un engrais complet N-P-K est d'un emploi plus coûteux que le superphosphate seul mais le rendement obtenu n'est pas beaucoup plus élevé. Les engrais inorganiques n'ont qu'un effet limité dans les étangs où la productivité due aux éléments minéraux a déjà atteint son maximum.

AUMENTO DE LA PRODUCCION DE LOS ESTANQUES PISCICOLAS DE AGUA DULCE MEDIANTE EL EMPLEO DE ABONOS INORGANICOS

Extracto

La administración de 8 estanques con una superficie de 39,6 hectáreas en una granja piscícola de Taiwán registró pérdidas económicas durante 7 años consecutivos. Mediante el empleo de abonos superfosfatados en 1965, se logró cambiar de una pérdida, al parecer irrecuperable, a la obtención de beneficios. Una abundante repoblación con carpas plateada y de cabeza grande, que se alimentan de plancton, en combinación con otras condiciones favorables, contribuyeron a los sorprendentes resultados obtenidos. El experimento demostró que, aunque una dosis elevada de 180 Kg/ha de P_2O_5 da un rendimiento íctico lo suficientemente elevado para obtener beneficios, la dosis más eficaz y económica es de 40 Kg/ha, ya que el rendimiento de pescado no es proporcional con la dosis de P_2O_5. El experimento reveló también que cuanto más elevada es la productividad de un estanque tanto menos fertilización con P_2O_5 es necesaria; quizás sean suficientes 20 Kg/ha para mantener un alto nivel de producción. Aunque el empleo de fertilizantes completos N-P-K representa más gastos que el uso de superfosfato solamente, no por ello da un rendimiento mucho más elevado. El efecto de los abonos inorgánicos es limitado en los estanques en los que la productividad ha alcanzado ya su máximo rendimiento debido a los elementos minerales nutrientes.

1 INTRODUCTION

No commercial use has as yet been made of chemical fertilizers to enrich the freshwater fish ponds in Taiwan. Therefore, the Chupei Station of the Taiwan Fisheries Research Institute, with technical and financial assistance from the Joint Commission on Rural Reconstruction, undertook some preliminary experiments from 1962 to 1964. In 1965, it carried out experiments and demonstrations in the Chupei Station's own experimental ponds, in three farmers' ponds and in eight of the 120 irrigation reservoir type ponds of the Taoyuan RETSER (Retired Servicemen) Fish Farm with remarkable results, although such experiments could not be considered as conclusive until repeated for another two years (1966-1967). This paper is an account of the results obtained from these experiments and demonstrations.

2 FISH POND CONDITIONS AND PROBLEMS IN TAOYUAN

The 120 ponds under the management of the Taoyuan RETSER Fish Farm with a total water surface of 854 hectares constitute a part of the Taoyuan canal irrigation system, which consists of 241 pond units covering approximately 2,112 hectares. These reservoir type of ponds were built many years ago to serve primarily the purpose of irrigation, and were not used for fish production in the early years. Their depths vary from three to eight metres or more depending on the topography of the land and water supply in different seasons. Pond sizes range from 2 to 28 hectares. The yellowish-brown bottom soil, indicating a deficiency of organic matter and mineral nutrients, has a pH value from 6 to 6.8, as has the water in the large reservoirs in the hills and the rivers which run over the acid soil before reaching the ponds. Unfortunately, no chemical analyses have been made to show the natural supply of mineral elements in these ponds.

The water does not remain stagnant all the year in these ponds. During late spring and summer, when rice is planted, some water is taken for irrigation, but is immediately replaced to more or less the previous level from reservoirs.

These reservoir ponds are good for fish growth, being open to the sunlight and to wind action, as there are no high trees around them. The water temperature in this area is favourable for fish production almost the whole year round, as the average lowest water temperature drops only to 14°C sometimes in January and February, rising to 16°C in March, 20°C in April, 24°C in May, 28°C in June and July, reaching the highest around 30°C in August and September and then dropping gradually to 20°C in December.

The Taoyuan RETSER Fish Farm was established in 1957, but records of stocking, harvesting and application of organic fertilizers were not adequately kept until 1959.

Up to the present, not all of the 120 ponds are stocked with fish, and of those stocked some are drained and harvested only once every two years, as the high cost of feeding and organic manuring limits the number of fish reaching marketable size within one year. When a pond is harvested once every two years, the prolonged culture period makes the cost of management too high for profit.

The high yield of a few ponds without application of inorganic fertilizers is evidently due, for one thing, to heavy application of organic manures (night soil and green manures) and, in addition, the ponds in comparatively low places receive plenty of nutrient-rich run-off from watersheds such as airfields, paddy fields, villages and urban grounds. Such conditions vary from pond to pond and their relationship to fish production needs further study. Among the 120 ponds of the Taoyuan Farm, the highest productions through heavy organic manuring alone were 1,164 kg/ha/year in 1963 (pond No.4012) and 1,150 kg/ha/year in 1964 (pond No.2011).

The majority of the 120 ponds are poor in production. Despite heavy use of organic manures, production in some of the ponds still has the tendency to fall. This is natural because they receive little or no additional mineral nutrients from the watershed to replace those lost through fish crop harvest and drainage, and the organic manures added are not sufficient to support a large phytoplankton bloom, so the fish crop naturally becomes low. A parallel is not difficult to find in newly constructed ponds where the fish crop is always high in the first two or three years and then drops to a lower and somewhat persistently low level as a result of mineral nutrient loss through harvest and drainage and, especially, of fixation of phosphorus in the bottom soil.

Pond Nos. 3008 and 2105 may be used as illustrations. They were fertilized only with organic fertilizers for the last seven years (Table I). In pond No. 3008 the fish yield dropped from 3,522 kg in 1958 to 2,499 kg in 1959 and was maintained at about that level for four years. In 1963 the yield declined further to 1,674 kg, though by 1964 the harvest rose slightly to 2,012 kg. The decline of yield in pond No. 2105 followed more or less the same pattern as pond No. 3008, but for 1964 the production climbed up to 8,271 kg as against 5,398 kg in 1963. One reason for this yield increase possibly lay in the increased amount of organic manures applied. Since stocking and survival rate of silver carp in the last three years, 1963-1965 were similar, there might be some other influences which require further investigation.

Table I

Fish production of two ponds of Taoyuan Fish Farm
for the period 1958 to 1965

Pond number and fertilizers used	1958	1959	1960	1961	1962	1963	1964	1965
3008 (4 ha)								
Nightsoil (ton)	no record	204	194	288	286	213	294	229
Grass (ton)	"	24	14	19	12	29	81	56
Total fish yield (kg)	3,522	2,499	2,631	2,185	2,063	1,674	2,012	1,935
2105 (8.8 ha)								
Nightsoil (ton)	no record	754	1,065	1,972	1,648	1,791	2,370	2,695
Grass (ton)	"	25	6	4	6	3	4	4
Total fish yield (kg)	5,997	5,065	4,606	5,200	4,301	5,398	8,271	5,763

The sudden drop of fish yield in pond No. 2105 again from 8,271 kg in 1964 to 5,763 kg in 1965 was rather unusual. This might be the result of a series of complex interactions between several factors such as cut-off of allochthonous nutrients, lower temperature, shortage of water or change of stocking rate, but as all these look improbable, the overdose with nightsoil appears to be one of the main causes responsible for the decline (Table I). The pond was, in effect, highly polluted, and the high biological oxygen demand under such conditions will retard fish growth and in extreme cases may cause drastic fish kill.

The eight ponds selected for use in the present experiments belong to the poor production group, though not the poorest, of the 120 ponds. The average yield of the 76 ponds under cultivation for six years from 1959-1964 before phosphate was applied was 403 kg/ha/year (Table II), while that of these eight ponds for the same period was 349 kg/ha/year (Table III). The operation of the eight ponds resulted in an annual deficit of from NT$134 to NT$1,019 [1] per pond as seen from the records of expenses and earnings of each pond for the period 1959 to 1964. It was for this reason that the management, at the suggestion of the Chupei Station of the Taiwan Fisheries Research Institute, agreed to the use of these eight ponds for the experiment and demonstration in the hope that some improvement could be made to help the economy of the farm.

Table II

Annual production of the ponds of Taoyuan Fish Farm without application of inorganic fertilizers

Year	Total area cultivated (ha)	Total production (kg)	Mean (kg/ha/year)
1959	517.44	226,184	437
1960	437.62	191,160	436
1961	590.82	211,359	357
1962	442.76	194,766	439
1963	532.57	192,129	360
1964	732.08	287,258	390
Mean			403

Table III

Six years' (1959-1964) average production of the eight ponds assigned for treatment with superphosphate and that of the nine ponds used as control of the Taoyuan RETSER Fish Farm and average doses of organic fertilizers used before treatment

Pond No.	Area (ha)	Gross yield (kg/ha/year)	Chicken manure (kg/ha/year)	Nightsoil (ton/ha/year)	Green manure (kg/ha/year)
5002	4.4	470	-	112	8179
5003	4.8	355	-	77	4956
6006	4.0	379	1420	23	2944
6009	4.0	440	1418	31	3469
7009	5.6	191	-	24	2718
8102	4.8	292	-	64	888
8103	4.8	364	1205	39	1599
8104	7.2	271	794	24	955
Mean		349		49	3338
Control ponds	45.0	325	-	45	2939

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[1] NT$40 = US$1

3 THE EXPERIMENT DESIGN

The present experiments were designed bearing in mind results of previous work in various parts of the world. The striking effects of phosphate fertilizers on fresh-water pond fish yields are now well known (Probst, 1950; Mortimer, 1954; Dendy, 1963).

The experiments carried out at Malacca (Hickling, 1962; Malacca, 1963) suggested a roughly linear relationship between P_2O_5 doses and yield of fish (from 344 kg/ha/year at 9 kg/ha P_2O_5 dose to 890kg/ha/year at 36 kg P_2O_5 dose). If such linear relationship persists, it would be more profitable commercially to use the maximum quantity of phosphate to obtain the highest possible fish production, because fertilizer is much cheaper than fish. However, experiments in Japan (Oguyama et al.,1962; Tominaga et al.,1964) hinted that overdoses of fertilizers are not profitable, although there is a residual effect from year to year.

At Malacca treatments with potash, nitrogen compounds and organic fertilizer (cow dung) gave disappointing results, heavy doses of K_2O and N in the form of urea even depressing the yield (Malacca, 1963). In U.S.A., however, Swingle and Smith (1939) found that application of $CaH_4(PO_4)_2 - NaNO_3 - KCl - CaCO_3$ gave higher yields than superphosphate alone.

Previous experiments in Taiwan (Liu and Wu, 1964) involved too many kinds of organic and inorganic fertilizers to show which nutrients were responsible for stimulating fish growth.

Superphosphate is the cheapest fertilizer available in Taiwan and as its value has already been shown elsewhere, it was decided to use superphosphate in some of the experimental and demonstration ponds.

As it was impossible to use superphosphate alone, because the reservoir type ponds were operated as a commercial enterprise and the farmers were afraid of losing money by interrupting their traditional practice, it was decided to continue exactly what had been done before, including stocking rate, manuring, harvesting, etc., except that absolutely no supplemental feeding was done.

As the dosage of phosphate showed a linear relationship with fish yield, to a certain limit in previous experiments, it was planned to determine the maximum limit for which phosphate could be used with profit. It is well known that overdose is a waste and underdose will not give adequate production. As the results of former experiments at Ueda (Oguyama et al., 1962; Tominago et al., 1964) and at Chupei Station (Liu and Wu, 1964) showed, the application of P_2O_5 at a rate of 280 kg/ha did not promote fish yield to any marked degree than with P_2O_5 at 150 kg/ha or even less. In consideration of these data and from personal observations during experiments conducted by the senior writer in previous years (Lin, 1962), it was postulated that a dose of P_2O_5 at 200 kg/ha should be the maximum, for any dose above this limit would simply be a sheer waste and give no additional increase in fish crop. A dose of 180 kg/ha might still be a dose to be employed with profit because, as mentioned before, superphosphate costs only about one-tenth of marketable value of fish.

With the above points as criteria, the experiments were designed in three parts as follows:

3.1 Superphosphate treatments in Taoyuan RETSER Fish Farm

Pond No.	Area (ha)	Nutrient P_2O_5 (kg/ha)	Equivalent commercial superphosphate (kg/ha)	Total quantity (kg)
5002	4.4	120	666.6	2,933
5003	4.8	180 + 1,042 $CaCO_3$	1,000.0 + 5,000 $CaCO_3$	4,800
6006	4.0	80 + 1,250 $CaCO_3$	444.4 + 5,000 $CaCO_3$	1,778
6009	4.0	40	222.2	889
7009	5.6	120	666.6	3,733
8102	4.8	180	1,000.0	4,800
8103	4.8	80	444.4	2,133
8104	7.2	40	222.2	1,600
Total	39.6			22,666

Nine ponds nearby with a total area of 45 hectares were used as control.

3.2 Farm ponds with N-P-K treatments

Name of pond	Area (ha)	Nutrients (kg/ha)	Commercial products (kg/ha)	Total quantity (kg)
Fu Kang	2.0	N 20 P_2O_5 40 K_2O 20	500	200.0 $(NH_4)_2SO_4$ 444.4 $Ca(H_2PO_4)_2$ 72.7 KCl
Ta Chu Wei	4.0	N 40 P_2O_5 80 K_2O 40	1,000	800.0 $(NH_4)_2SO_4$ 1,777.6 $CaH_4(PO_4)_2$ 290.8 KCl
Te Sheng Chun	2.5	N 80 P_2O_5 160 K_2O 80	2,000	1,000.0 $(NH_4)_2SO_4$ 2,222.2 $CaH_4(PO_4)_2$ 363.5 KCl
Total	8.5			2,000.0 $(NH_4)_2SO_4$ 4,444.2 $CaH_4(PO_4)_2$ 727.0 KCl

3.3 Experimental ponds in Chupei Fish Culture Station

Pond No.	Area (ha)	Nutrients (kg/ha)			Equivalent commercial fertilizer (kg/ha)	Total quantity (kg)
		N	P_2O_5	K_2O		
1	0.061	40	80	40	1,000	61
2	0.064	20	40	20	500	32
3	0.048	0	80	0	444	21
4	0.048	0	40	0	222	11
5	0.037	0	0	0	control	
Total	0.258					125

The 17 RETSER Farm ponds were stocked with the major species for polyculture following the old Chinese traditional practice as follows:

Species	Length (mm)	Wt (g)	Number per ha
Silver carp (*Hypophthalmichthys molitrix*)	100		600
Bighead (*Aristichthys nobilis*)	120	70	50
Mullet (*Mugil cephalus*)	30		600
Grass carp (*Ctenophyaryngodon idella*)	120		30
Common carp (*Cyprinus carpio*)	30		500
Perch (*Lateolabrax japonicus*)	10		160
Others (mud carp, catfish, goldfish, etc.)			1,000
Total			2,940

4 PROCEDURE OF APPLICATION OF FERTILIZERS

Specified quantities of fertilizers for each experimental pond were applied in different proportions in different months according to temperature variations as follows:

Period	Month	Temperature (°C)	Proportion of fertilizers (%)
1	April and May	16 - 20	19
2	June to September	20 - 28	72
3	October	16 - 18	9
4	November to December	12 - 14	0
Total			100

The amount of fertilizers for each period was equally divided for daily application or, alternatively, for weekly or once every five days in whatever manner was convenient to the operator; but the important thing was that the fertilizer was first completely dissolved in a container and then spread as evenly and over as large a surface of the pond as possible and in a different area each time.

5 RESULTS AND DISCUSSION

5.1 The seventeen ponds of Taoyuan RETSER Farm

The results of this part of the experiment are shown in Table IV. When they are compared with Table III and the controls, an average increase of 383 and 476 kg/ha/year respectively of fish yield due to the treatment of superphosphate is evident; the effectiveness of superphosphate for fish production seems to be independent of the quantity of nightsoil and green manures supplied.

There exists no linear relationship between doses of phosphate and fish yield as found in Malacca. Neither does the quantity of any organic manure show well-defined relationships with the fish crop. With a heavy dose of P_2O_5 at the rate of 180 kg/ha, the limiting effect appears to be better than with the lighter dose of P_2O_5. In the case of P_2O_5 180 kg/ha, a yield of 863 kg/ha with liming was obtained as against 630 kg/ha without liming, but in the case of P_2O_5 80 kg/ha, the addition of $CaCO_3$ stimulated a fish increase of only 52 kg/ha (774 against 722 kg/ha).

Table IV

First year fish production of the eight ponds of the Taoyuan RETSER Farm treated with superphosphate and the average fish production of the nine control ponds in 1965

Pond No.	Area (ha)	Gross yield (kg/ha/year)	P_2O_5 (kg/ha/year)	Nightsoil (ton/ha/year)	Green manure (kg/ha/year)
5002	4.4	835	120	73	3635
5003	4.8	863	180 + $CaCO_3$ 1042 kg	91	2490
6006	4.0	774	80 + $CaCO_3$ 1250 kg	22	1826
6009	4.0	844	40	28	1635
7009	5.6	556	120	13	1452
8102	4.8	630	180	56	606
8103	4.8	722	80	41	3669
8104	7.2	637	40	36	1090
Mean		732		45	2050
9 control ponds	45.0	256	0	35	1988

As no definite relationship seems to exist between doses of P_2O_5 and fish crops, a mean yield of the eight ponds may be useful in facilitating comparison for instance between yield before and after treatment. On this basis data are obtained as shown in Table V and Figs. 1 and 2.

Table V

Comparison between the six years (1959-1964) mean weight in kg of each major species in the eight ponds of Taoyuan RETSER Fish Farm before treatment and in the first year after superphosphate treatment

Species	5-years' mean production and mean weight of each species of the 8 ponds before treatment			First year means after treatment		
	kg/ha/year		Mean weight of each species (kg)	kg/ha/year		Mean weight of each species (kg)
Silver carp	181	47.0%	0.64	381	53.0%	1.52
Bighead	58	15.0%	2.16	155	21.6%	3.18
Common carp	18	4.6%	0.35	17	2.4%	0.16
Mullet	28	7.3%	0.39	55	7.7%	0.35
Grass carp	26	6.7%	1.20	26	3.6%	0.80
Perch	17	4.4%	0.44	25	3.5%	0.65
Others	58	15.0%		58	8.2%	-
Total	386	100.0%		717	100.0%	

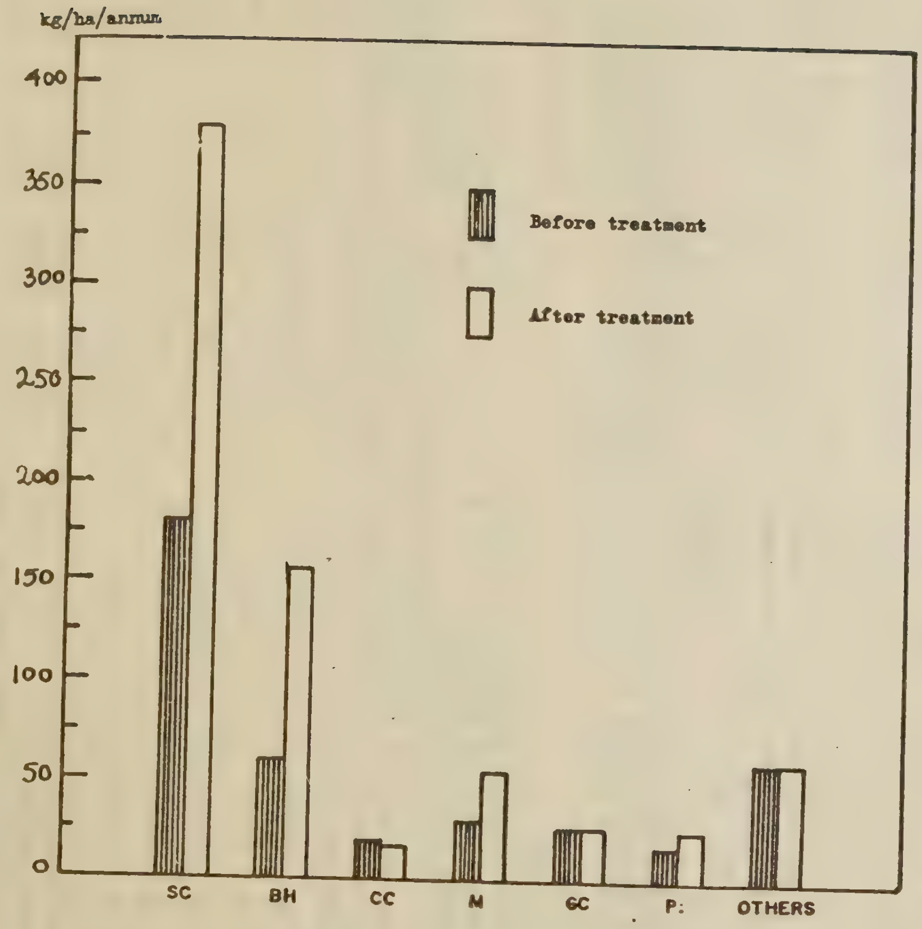

Fig. 1 Comparison of six years' (1959-1964) mean production in kg/ha/ year of each major species in the eight ponds of Taoyuan RETSER Farm before treatment, with that of the first year's mean after superphosphate treatment. BH, bighead; CC, common carp; GC, grass carp; M, mullet; PE, perch; SC, silver carp.

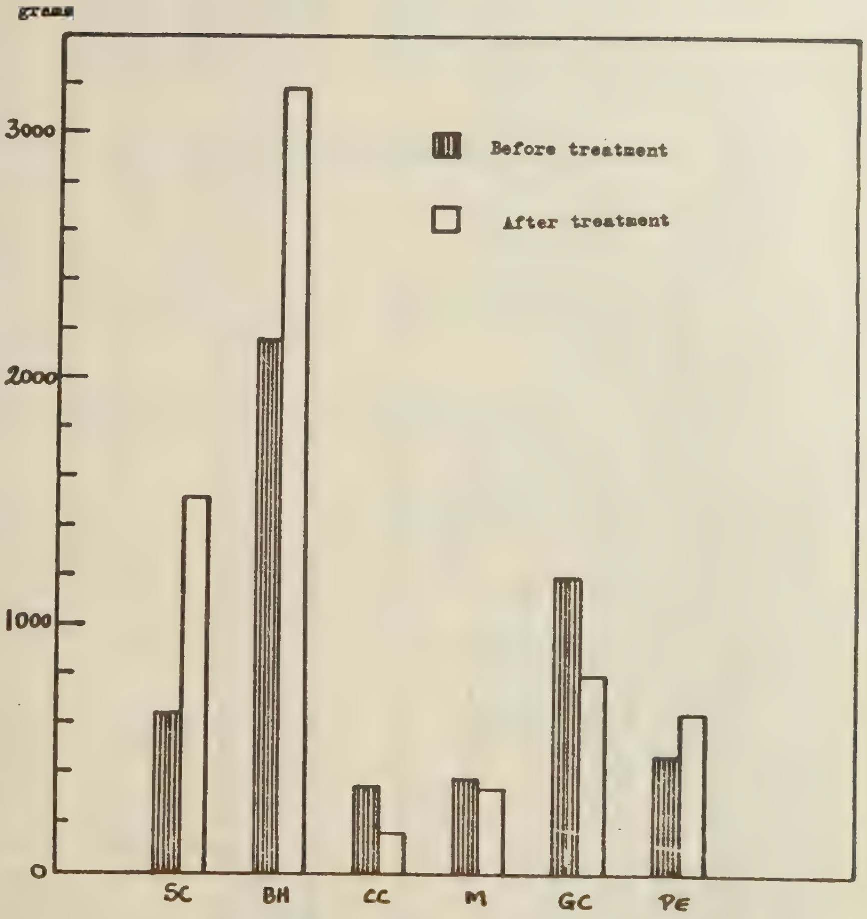

Fig. 2 Comparison of six years' (1959-1964) mean weight of each major species in the eight ponds of Taoyuan RETSER Farm before treatment with that of the first year's treatment with superphosphate. BH, bighead; CC, common carp, GC, grass carp; M, mullet; PE, perch; SC, silver carp.

These data show that the principal effect of P_2O_5 is on the growth of fish which feed on phyto- and zoo-plankton, (i.e. silver carp and bighead respectively). The total increase of yield of these two species was the result of individual gain in weight, as the silver carp increased almost three times after P_2O_5 treatment and the bighead increased about one-third or more.

This is evidently due to the fact that silver carp possesses the shortest trophic chain directly from phytoplankton to fish, and superphosphate is an efficient stimulant for phytoplankton growth, particularly those easily digestible diatoms upon which the silver carp feed (Prowse, 1961; 1963). The abundance of phytoplankton also supports a large population of zooplankton which in turn is food for the bighead.

As shown in Table V, the common carp was not benefited by P_2O_5. Neither did the grass carp increase in weight after treatment. The reason for this is not clear and requires further study.

The fact that the net increase of fish crop in 1965 has turned each of the eight ponds from an average annual loss of NT$203 - NT$1,344 in the past six years when no inorganic fertilizers were used to a profit of NT$2,427 to NT$5,963 for 1965 after treatment with superphosphate, gives the management of the Taoyuan Farm confidence in using phosphate next year in all its ponds.

The results of this part of the experiment also indicate that the lowest dose of 40 kg/ha of P_2O_5 gives a net fish yield of 288 to 395 kg/ha/year which is better than that from 120 kg/ha of P_2O_5, though inferior to those of 80 and 180 kg/ha of P_2O_5 which range from 207-386, 373-425 and 281-514 kg/ha respectively. These figures are obtained by subtracting from the gross fish yield of each pond fertilized the six-year average of the eight ponds unfertilized. (For example, in pond 6009, P_2O_5 40 kg/ha, the net yield kg/ha is equal to 844 - 349 = 395 kg/ha). If from the gross fish yield of each fertilized pond is subtracted the average control yield, the net increase due to superphosphate will be even higher.

Assuming the dosage of 40 kg/ha to be adequate, we can calculate that one kg of P_2O_5 is capable of producing nearly 10 kg of marketable fish. As one kg of P_2O_5 costs about NT$10 and 10 kg of fish would be worth NT$150, it is beyond doubt that superphosphate is the most economical fertilizer yet tested for fish production.

5.2 Farm ponds with N-P-K treatments

The results of this part of the experiment (Table VI) are in general agreement with those of the first part. They show no particular value of nitrogen and potash as nutrients in these reservoir ponds, although the yields in these three ponds are slightly higher. Because the private farmers do not keep good records and their supervision is not as adequate as in the Taoyuan RETSER Fish Farm, no direct comparison can be made. However, the effectiveness of the complete fertilizers is conspicuous.

Table VI

Results of experiments in the three farm ponds receiving N-P-K treatments

Name of pond	Area (ha)	5-year average production before treatment (kg/ha/year)	Fertilizers N-P-K (kg/ha)	First year yield after treatment (kg/ha/year)	Net increase (kg/ha /year)	Increase % over unfertilized
Fukang	2.0	600	20-40-20	1260	660	110
Ta Chun Wei	4.0	165	40-80-40	824	659	399
Te Sheng Chun	2.5	186	80-160-80	916	730	392

5.3 The experimental ponds in Chupei Station

This part of the experiment was intended for comparison with the reservoir pond experiments. The results are similar to those of the first and second parts, but these results give a general indication that the use of phosphate alone in fish ponds is just as good as complete fertilizers (N-P-K). In the absence of organic fertilizers, phosphates appear to be equally effective as shown in the Chupei ponds (Table VII) though the Chupei ponds might have had residual effects from various fertilizers employed in experiments of previous years. The high productivity of the control pond No. 5 supports this postulation.

Table VII

Results of experiments in Chupei Station

Pond No.	Area (ha)	Fertilizers N-P-K (kg/ha)	Yield (kg/ha/year)
1	0.061	40 - 80 - 40	882
2	0.064	20 - 40 - 20	727
3	0.048	0 - 80 - 0	739
4	0.048	0 - 40 - 0	718
5	0.037	0 - 0 - 0	713

6 CONCLUSIONS

As the experiments were planned to continue for two or three more years, it is rather early to draw any definite conclusions from the observations made in this first year's experiments. However, there are a few points of significance which can serve as a useful guide for planning further experiments.

6.1 The present experiments show that superphosphate alone is most efficient for fresh-water pond fertilization in Taiwan, for one kg of P_2O_5 can produce 10 kg of marketable fish equivalent to the expense of one dollar in fertilizer to earn 15 dollars in fish[1]. In comparison, organic fertilizers are much more expensive and inefficient. At the rate as used by the Taoyuan Farm, 140 kg of nightsoil are required to produce one kg of marketable fish. If the nightsoil is valued at NT$0.10 per kg - sometimes NT$0.20/kg dependent on distance of transportation, the cost of production in fertilizers alone amounts to NT$14 per kg, thus leaving a very small margin of profit.

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[1] Commercial $CaH_4(PO_4)_2$ is valued at NT\$170 per 100 kg which contains 18 percent of P_2O_5. One kg of P_2O_5 would cost approximately NT\$10. Ten kg of fish would fetch about NT\$150.

6.2 The heavy stocking with silver carp, which on account of its phytoplanktophagic habit has the shortest food chain, means that phosphate is most efficiently utilized for the benfit of the fish. The silver carp is a big and fast growing fish attaining one to two kg in a year. This, together with the long period of favourable temperature in subtropical Taiwan, provides the silver carp with optimum conditions for grazing on the planktonic "pasture", which grows rapidly and for long duration as long as phosphate is supplied in sufficient quantity.

6.3 The technique in which the superphosphate is first completely dissolved in a bucket before spreading over the water surface and applications are made daily or at least six times a month, and in quantity adjusted for the rise and fall in temperature, appears to be helpful for full utilization of the fertilizer. Applied in this manner, the loss of phosphorus due to the formation of insoluble phosphates with iron and aliminium is reduced to a minimum, for there are reasons to believe that a large portion of the dissolved superphosphate is assimilated before sinking to the bottom to become fixed as insoluble salts.

6.4 Polyculture is a system which contributes efficiently to the high yield of ponds, and in this connection the part played by the grass carp with respect to the trophic chain in ponds deserves a short discussion. The grass carp is a voracious vegetable feeder; it devours aquatic grass up to 72 percent or land grass to 48 percent of its own weight per day. As it cannot digest all the food taken in, at least about half or more is discharged as faeces, which are good fertilizers for planktonic growth. Since the silver carp and bighead are principally plankton feeders they benefit from the presence of the grass carp. Therefore, it is the traditional Chinese polyculture practice to feed only the grass carp with plenty of green grass or silkworm waste (faeces of silkworm consisting of undigested and residual mulberry leaves) and to leave the silver carp and bighead to feed partly on the digestible detritus from the faeces of the grass carp and partly on the plankton that has developed thereby. In such cases, no inorganic fertilizers were applied to the ponds and the water was somewhat clear to permit the growth of some aquatic plants for the grass carp to feed. However, in the experimental ponds in Taoyuan a different situation arises as a result of inorganic fertilizer application. Light is completely cut off from the bottom of the ponds by the plankton bloom and no rooted aquatic plants can grow for the grass carp to feed on, resulting in decrease of grass carp production, but, of course, in this instance the tremendous production of silver carp more than compensates for the loss in grass carp, and thus a higher total yield is obtained by addition of the grass carp to other species in polyculture.

6.5 Another species which benefited by phosphate fertilizer was the bighead, whose net weight increase due to fertilizing the ponds amounted to 167 percent (Table V).

6.6 There is no linear relationship between the dosage of P_2O_5 and fish yield as shown by the results of this first year's experiment, but the percentage of fish yield with fertilizer is much higher in low natural production ponds than in higher ones. For example, pond No. 7009 produced 191 kg/ha/year prior to and 556 kg/ha/year after treatment, a 191 percent increase over pre-fertilization yield, but pond No. 5002 with a production of 470 kg/ha/year yielded 835 kg/ha/year by fertilization, an increase of only 77 percent. Again the Fukang pond with the highest prefertilization production of 600 kg/ha/year among the three farm ponds, produced only 110 percent more by fertilization, while the Ta Chu Wei pond with production of 165 kg/ha/year produced 399 percent more when fertilized.

These results suggest the following criteria for use in future tests of phosphate fertilizers when silver carp and bighead constitute the principal fishes in polyculture:

Pre-fertilization production (kg/ha/year)	P_2O_5 needed (kg/ha)
< 200	80
400	60
600	40
800 <	20

6.7 The present experiment does not show decisively the effect of $CaCO_3$ on fish yield, but liming may be beneficial for slightly acid ponds in combination with high dosage of P_2O_5. Further data are needed to elucidate this.

6.8 The partial renewal of water by irrigation is favourable for fish growth, because this helps to aerate the richly fertilized ponds. As is well known, any well-fertilized stagnant pond exhibits plankton blooms and changes in standing crop, and the resulting biological oxygen demand may reach so high a point that not only is fish growth retarded, but also drastic fish kills may occur. To relieve such a critical situation, the most convenient and practical measure is to renew the water partially whenever needed, or regularly at intervals, to increase the oxygen supply. This is exactly what has happened in the reservoir ponds of Taoyuan Fish Farm.

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8 REFERENCES

Dendy, J.S., 1963 Farm ponds. In Limnology in North America, ed. by D.G. Frey, pp.595-620 Madison. University of Wisconsin Press

Hepher, B., 1958 On the dynamics of phosphorus added to fish ponds in Israel. Limnol. Oceanogr., 3(1):84-100

____________, 1962 Primary production in fish ponds and its application to fertilization experiments. Limnol.Oceanogr., 7(2):131-6

Hickling, C.F., 1962 Fish culture. London, Faber and Faber, 295 p.

Lin, S.Y., 1962 Experiment on the effect of inorganic fertilizers on carp growth in ponds. 8 p. (Ms.)

Liu, C.K. and S.F. Wu, 1964 Experiments on fresh-water pond fertilization. Bull.Taiwan Fish.Res.Inst., (9):83-94 (in Chinese)

Malacca, Tropical Fish Culture Research Institute, 1960 Rep.trop.Fish Cult.Res.Inst.Malacca, 1959-60:28 p.

____________, 1961 Rep.trop.Fish Cult.Res.Inst.Malacca, 1960-1961:31 p.

Malacca, Tropical Fish Culture Research Institute, Rep.trop.Fish Cult.Res.Inst.Malacca,
1962 1961-1962:28 p.

__________, Rep.trop.Fish Cult.Res.Inst.Malacca, 1963:41 p.
1963

Mortimer, C.H., Fertilizers in fish ponds. Fish.Publ.,Lond., (5):155 p.
1954

Oguyama, T. et al., A study on the improvement of pond productivity by fertilization.
1962 Rep.Freshw.Res.Inst.Ueda Stn., 1961:29 p. (in Japanese)

Probst, E., Teichdüngung. Allg.Fisch.Ztg, 75(8/9)
1950

Prowse, G.A., The use of fertilizers in fish culture. Proc.Indo-Pacif.Fish.Coun.,
1961 9(2):73-5

__________, Neglected aspects of fish culture. Curr.Aff.Bull.Indo-Pacif.Fish.Coun.,
1963 (36):8 p.

Schäperclaus, W., Lehrbuch der Teichwirtsehaft. Berlin, P. Parey, 582 p.
1961

Swingle, H.S., Experiments on pond fertilization. Bull.Ala.agric.Exp.Stn., (264)
1947

Swingle, H.S. and E.V. Smith, Fertilizers for increasing the natural food for fish in
1939 ponds. Trans.Amer.Fish.Soc., 68:126-35

Tang, Y.A. and T.P. Chen, The use of chemical fertilizers in the milkfish ponds of
1957 Taiwan. Fish.Ser.jt.Comm.rur.Reconstr.China, (3):19 p.

Tchang, W.H., The past and future of the Taoyuan RETSER fish farm. Chin.Fish.Non.,
1962 (117):11:2 (in Chinese)

Tominaga, M., et al., A study on the improvement of pond productivity by fertilizers.
1964 Rep.Freshw.Res.Inst.Ueda Stn., 1963:19 p. (in Japanese)

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II/E-12

PRODUCTIONS OF TILAPIA MOSSAMBICA PETERS, PLANKTON AND BENTHOS AS PARAMETERS FOR EVALUATING NITROGEN IN POND FERTILIZERS [1]

by

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Abstract

Twelve 0.1 ha earth ponds were used for this study. Four ponds received no fertilization, 0-0-0 (N-P-K), four received non-nitrogenous 0-8-2 (N-P-K) fertilization, and four received nitrogenous 8-8-2 (N-P-K) fertilization, the same fertilizer treatments which had been applied for the previous five years. Rates of stocking for each fertilizer treatment were 4,942; 9,884; 14,826 and 19,768 fish per ha. The duration of the experiment was from July to October 13-14. Increases in weights of fish per kg were determined upon draining of ponds. Unfertilized ponds produced an average of 242.6 kg per ha. The minimum and maximum rates of stocking resulted in production of 225.9 and 284.7 kg per ha, respectively. The two fertilizer treatments resulted in productions that were essentially alike. In fertilized ponds the average productions with increase in rates of stocking were 342.0, 695.3, 760.1, and 836.7 kg per ha, respectively. The study included rates of growth and reproduction of fish; abundance of plankton, including a volumetric analysis; and abundance of benthos. Results indicated increase in production with increase in rates of stocking and from 63 to 199 percent greater production in fertilized ponds than in unfertilized ponds. However, the elimination of nitrogen from fertilizer for six years did not result in a decline in fish production when water temperature remained above 22°C.

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II/E-12

LES PRODUCTIONS DE *TILAPIA MOSSAMBICA* PETERS, DE PLANCTON ET DE BENTHOS UTILISEES COMME PARAMETRES POUR EVALUER L'EFFET DE L'AZOTE DANS LES ENGRAIS EMPLOYES EN ETANG.

Résumé

Douze étangs en terre d'une superficie de 0,1 ha ont été utilisés au cours de ces expériences. Quatre étangs n'ont pas été fertilisés, 0-0-0 (N-P-K); 4 ont été traités avec un engrais non azoté, 0-8-2 (N-P-K); et 4 l'ont été avec des engrais azotés, 8-8-2 (N-P-K); soit les mêmes formules qui avaient été appliquées depuis 5 ans à ces étangs. Dans chaque groupe, quatre taux d'empoissonnement ont été utilisés, à savoir: 4 942, 9 884, 14 826 et 19 768 poissons par hectare. L'expérience a duré du mois de juillet aux 13-14 octobre. L'accroissement en poids des poissons dans chaque étang a été determiné lors de la mise à sec. Les étangs non fertilisés ont donné une production moyenne de 242,6 kg par ha. Les taux de charge minimum et maximum ont donné respectivement une production de 225,9 et de 284,7 kg par ha. Les deux formules d'engrais ont donné des productions sensiblement analogues. Dans les étangs fertilisés, la production moyenne, rapportée aux taux d'empoissonnement a été respectivement de 342,0; 695,3; 760,1; et 836,7 kg par ha. L'étude a également porté sur le taux de croissance et de reproduction des poissons, l'abondance du plancton, y compris son analyse volumétrique, et l'abondance du benthos. Les résultats montrent que la production s'est accrue à mesure qu'ont augmenté les taux d'empoissonnement et que la production des étangs fertilisés a été supérieure de 63 à 199 pour cent à celle des étangs non fertilisés. Toutefois, l'élimination de l'azote dans les engrais pendant six ans n'a pas entraîné de réduction de la production de poissons lorsque la température de l'eau est demeurée supérieure à 22°C.

PRODUCCIONES DE *TILAPIA MOSSAMBICA* PETERS, PLANCTON Y BENTOS COMO PARAMETROS PARA LA EVALUACION DEL NITROGENO EN LOS FERTILIZANTES PARA ESTANQUES

Extracto

Para este estudio se utilizaron doce estanques de tierra de 0,1 ha. Cuatro de ellos no recibieron fertilización, 0-0-0 (N-P-K), cuatro la recibieron no nitrogenada 0-8-2 (N-P-K) y cuatro la recibieron nitrogenada, 8-8-2 (N-P-K). Estos tratamientos de fertilizantes eran los mismos que los aplicados en los cinco años anteriores. El número de indivíduos con que estaban poblados los estanques para cada tratamiento era de 4.942, 9.884, 14.826 y 19.768 peces por hectárea. La duración del experimento fue de julio a 13-14 de octubre. El aumento de los peces fue determinado por vaciamiento de los estanques. Los no fertilizados produjeron un promedio de 242,6 por hectárea. Las densidades de población mínima y máxima dieron produciones de 225,9 y 284,7 Kg por hectárea respectivamente. Los dos tratamientos con fertilizantes determinaron producciones que fueron fundamentalmente análogas. En los estanques fertilizados la producción media al aumentar las densidades de repoblación fue de 342,2, 695,3, 760,1 y 836,7 Kg por hectárea, respectivamente. El estudio abarca las tasas de crecimiento y reproducción de los peces; la abundancia de plancton, incluído un análisis volumétrico; y la abundancia de bentos. Los resultados señalaron un aumento de la producción al aumentar las densidades de repoblación, y un aumento del 63 al 199 por ciento de la producción en los estanques fertilizados respecto a los no fertilizados. Sin embargo, la eliminación de nitrógeno del fertilizante durante seis años no dió por resultado el descenso de la producción piscícola cuando las temperaturas del agua se mantuvieron por encima de 22°C.

1 INTRODUCTION

1.1 Background information

In 1959 experiments were begun at Auburn University Agricultural Experiment Station, Auburn, Alabama, to determine the effects of omitting nitrogen from the N-P-K (N, P_2O_5, and K_2O) fertilizer commonly used in fish ponds. Twelve 0.1 ha earth ponds, which had received the same fertilizer treatments annually since 1959, were used in this study. Beginning in 1959, four ponds received no fertilizer, designated as the 0-0-0 treatment; four received P_2O_5 and KCℓ, designated as the 0-8-2 treatment or the non-nitrogenous fertilizer treatment; and four received N, P_2O_5, and KCl, designated as the 8-8-2 treatment or the nitrogenous fertilizer treatment. The potassium was included to avoid a possibility of deficiency of this element, so that the comparison would be the effectiveness of nitrogen in the fertilizer mixture. Through the years since 1959 various fishes and stocking rates have been used to measure effects of the three fertilizer treatments. The bottom of each pond sloped gently from a depth of 0.6 m at one end to a maximum depth of 1.5 m at the other. The bottom soil was sandy clay at the shallow end, and gradually changed to soft mud ooze at the deep end. Each pond could be filled and drained individually. Water entering the ponds passed through monofilament Saran screens to eliminate unwanted fish.

This paper reports the results of three concurrent cooperative studies conducted in 1964 to evaluate the omission of nitrogen from fertilizer when the ponds were stocked with *Tilapia mossambica* Peters at rates of 4,942; 9,884; 14,826; and 19,768 fish per ha with fish that ranged from 3.9 to 7.7 cm in length.

The ponds were drained and refilled in June 1964. The following amounts (kg/ha) of fertilizer were applied to the ponds on 17 and 23 June, 23 July, 19 August and 15 September 1964:

N-P-K Treatment	NH_4NO_3	Triple superphosphate	Potassium chloride
0-0-0	0	0	0
0-8-2	0	16.6	3.6
8-8-2	26.9	16.6	3.6

The fish were stocked on 6 June. The net productions were determined for each pond by subtracting the weight of fish stocked from the total weight obtained and are presented in Table I.

From Table I it can be seen that although the fertilizer treatments were replicated the stocking rates were not replicated within any fertilizer treatment.

Table I

Net total production of fish in kg per ha from 6 July to 13-14 October in ponds receiving different fertilizer treatments and different stocking rates of *Tilapia mossambica*

Rates of stocking per ha	Fertilizer treatment		
	0-0-0	0-8-2	8-8-2
4,942	225.9	368.7	315.2
9,884	258.8	693.6	697.8
14,826	200.8	742.4	777.8
19,768	284.7	851.7	821.7

1.2 Parameters studied

Since the weight/ha of fish produced is the primary concern in fish culture, the net production in weight per unit area was used as a parameter with which others were compared. Field work was done cooperatively by those responsible for studies of the various parameters.

A study of plankton was conducted by Varikul. It consisted of measuring dry weights of standing crops and of estimating volumes of dominant zooplankton, both in units per litre or sample.

A study of benthos was conducted by Sumawidjaja. It consisted of obtaining dry weights and numbers of dominant organisms from samples.

A study of fish was conducted by Potaros. It consisted of determining the growth and reproductive rates, and food habits of *T. mossambica*.

2 PLANKTON

2.1 Review of literature

Reports on evaluation of inorganic fertilizers for production of plankton have usually been on "complete" fertilizers, i.e. the inclusion of N, P_2O_5, and K_2O. Swingle and Smith (1939) reported the relative amounts of phosphorus to nitrogen utilized by plankton to range from 3:1 to 6:1. Neess (1949) mentioned the ability of aquatic organisms, such as bacteria and bluegreen algae to fix nitrogen so that it would be usable by phytoplankton, but also suggested that fertilization with phosphate only stimulated growth of rooted aquatic plants instead of phytoplankton. Hepher (1962) reported that addition of nitrogen in fertilizer for production of plankton was of greatest value in the spring, but was of little value in the summer. He postulated that nitrogen fixation was more effective in warm water than in cold waters.

The use of plankton as a source of food for *Tilapia mossambica* has been reported by various authors (Chen, 1953; Vaas and Sachlan, 1952; Hora and Pillay, 1962; Vaas, 1954; Kelly, 1955; and Prowse, 1961). However, there was a lack of agreement as to the value of various phytoplankton species to tilapia.

2.2 Materials and methods

2.2.1 Sampling

Three locations in each pond were sampled at three week intervals with a Kemmerer water sampler. At the shallow end samples were taken at the surface. At the deep end they were taken at the surface at a depth of 1.2 m. One litre of each sample was concentrated in a Foerst plankton centrifuge. The concentrate was transferred to a pre-weighed crucible, dried in an electric oven at 60°C for 24 to 48 hours, stored in a desiccator for 24 hours, and weighed to obtain dry weight of plankton per litre of sample. The remainder of the sample was measured and then concentrated in the centrifuge and preserved in five percent formalin for identifications and counts of zooplankters.

2.2.2 Identification of zooplankters

Permanent mounts on microscope slides were prepared for every dominant species of zooplankton. Identifications were made by the use of the keys given by Pennak (1953) and Edmondson (1959). Complete counts of the larger animals in each concentrate were made by the use of a stereoscopic microscope. For rotifers, subsamples were used and counts were made by the use of the Sedgwick-Rafter counting cell.

2.2.3 Volumes of zooplankton

Since different groups of animals that make up the zooplankton differ greatly in volume, the numbers of individuals of a species give little information regarding the importance of that kind of animal as food for fish. Therefore, numbers of individuals were converted into estimates of volumes in mm^3 per l of sample. This was done by constructing clay models of the animals that were in each dominant group of zooplankters. The volume of each model was determined by displacement of water in a graduated cylinder. The length, width, and depth of the model were measured and the volume was estimated by the following formula:

$$V = 1/3\,\pi \frac{(W + D)^2}{4} \times L$$

Where V = volume, L = length, W = width, and D = depth

A correction factor for volume of a given model was obtained by dividing the displacement of water by the estimated volume obtained from the formula.

Average lengths, widths, and depths of representative individuals in a group of animals were used for values to apply in the formula. The value obtained, when multiplied by the correction factor, was the estimated volume of the average individual of the group. This volume was multiplied by the number of individuals to give an estimate of the total value for the group.

2.3 Results

2.3.1 Dry weights

The dry weights of plankton from samples obtained at different stations and depths in ponds were not sufficiently different to indicate differences in the distribution of plankton within any pond.

The rates of stocking fish had little effect on the dry weights of plankton in fertilized ponds, whereas in unfertilized ponds the dry weights were greater in the ponds stocked with 19,765 fish per ha than in ponds that received lower stocking rates.

The average of dry weights of plankton per l of sample from ponds that received different fertilizer treatments and different rates of stocking are presented graphically in Fig. 1. Only on one occasion, 7 August, did the average dry weight of plankton from an unfertilized pond even slightly exceed that of the fertilized ponds with the same rate of stocking (19,768 fish per ha). Of the 16 sets of comparisons in Fig. 1, in 13 instances the average dry weights from ponds that received nitrogenous fertilizer treatments were greater than the average dry weights from ponds that received non-nitrogenous fertilizer treatments.

In fertilized ponds the dry weights increased between August and 18 September, and declined by 9 October. In unfertilized ponds the dry weights were approximately the same on all sampling dates, with some decline in October.

2.3.2 List of zooplankton

The kinds of zooplankton encountered are listed below:

- Cladocera
    - Sididae
        - _Diaphanosoma_ _brachyurum_
    - Daphnidae
        - _Daphnia_ _ambigua_
        - _Daphnia_ sp.
        - _Ceriodaphnia_

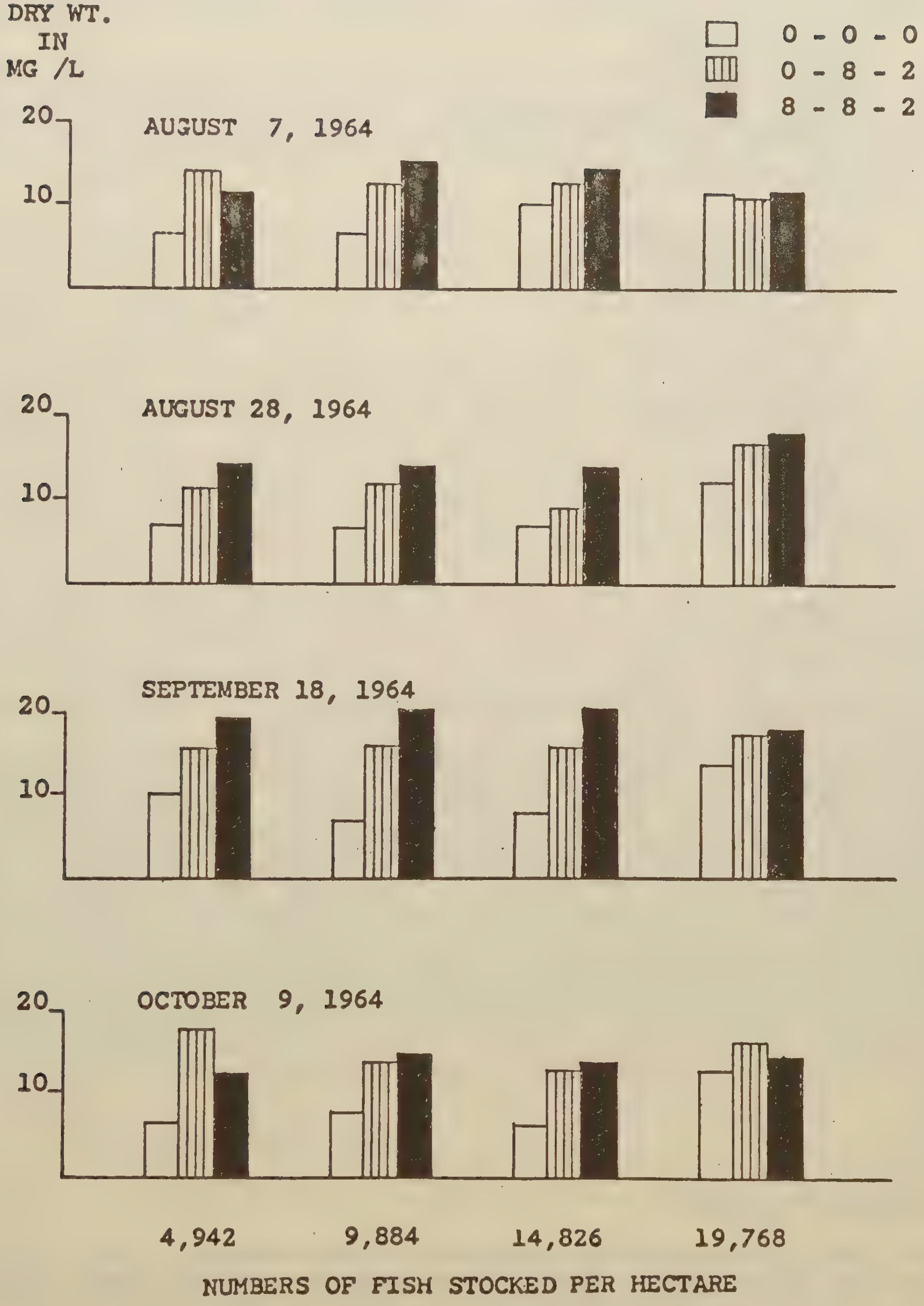

Fig. 1 Average dry weights of plankton in mg/l of samples obtained from fertilized and unfertilized ponds stocked with different numbers of *Tilapia mossambica*

  - Bosminidae
    - *Bosmina longirostris*
- Copepoda
  - Cyclopidae
    - *Mesocyclops edax*
    - *Cyclops exilis* Coker
    - *Cyclops* sp.
    - *Tropocyclops prasinus mexicanus*
  - Diaptomidae
    - *Diaptomus bogalusensis*
  - Rotifera
    - *Platyias quadricornis*
    - *Playtias patulus*
    - *Monostyla bula*
    - *Brachionus angularis*
    - *B. havanaensis*
    - *Tricocera multicrinis*
    - *Trichocera* sp.
    - *Anuraeopsis fissa*
    - *Keratella valga*
    - *Keratella* sp.
    - *Polyarthra* sp.
    - *Lecane* sp.
    - *Filinia* sp.
  - Others
    - Ostracoda
    - *Chaoborus*
    - Tubificidae
    - Nematoda

2.3.3 Estimated volumes of dominant zooplankton

The dominant groups of zooplankters included the Cyclopidae, Diaptomidae, nauplii, Sididae and Daphnidae, Bosminidae and Rotifera. The estimated volumes of Cyclopidae from fertilized ponds were greater than those from unfertilized ponds. The volumes from ponds that received the non-nitrogenous fertilizer treatments were approximately the same as those from ponds that received nitrogenous fertilizer treatment. The volumes of the Diaptomidae were approximately the same from fertilized and unfertilized ponds. The volumes of Sididae and Daphnidae and of nauplii from fertilized ponds were not uniformly different from those from unfertilized ponds. The volumes of Bosminidae were conspicuously greater from unfertilized ponds than from fertilized ponds. The relative abundance of this group according to the rates of stocking of fish was not consistent. The greatest average volume of Bosminidae per 1 of sample was 0.97 mm^3, and was obtained on 18 September from the unfertilized pond with the next to highest rate of stocking. The next greatest volume was 0.51 mm^3, and was obtained on 9 October from the unfertilized pond with the highest rate of stocking.

3 BENTHOS

3.1 Review of literature

Use of standing crops of benthos to evaluate effects of fertilization of waters has been reported by several authors; Howell (1942), Patriarche and Ball (1949), Ball (1949), Hayne and Ball (1956), Rabanal (1960), McIntire and Bond (1962), Liang (1964) and others. The standing crop consists of the organisms that are left after predation by fish. For this reason Hayne and Ball (1956) and Dendy (1956) warned against use of standing crop as a parameter of productivity unless the nature of the fish population and environmental factors are taken into consideration.

An adaptation of the multiple-plate sampler (Hester and Dendy, 1962) by supporting it with the plates held vertically and with one edge in contact with the bottom was reported by Liang (1964). An electrical stimulator that causes organisms to move and thus be seen easily was described by Bayless (1961) as an aid in separating benthic organisms from sand and debris.

Liang (1964) found that in winter, following summer fertilization, samples from the ponds that had received no fertilization contained less benthos than did samples from fertilized ponds, but the samples from ponds that had received the non-nitrogenous fertilizer treatments were essentially like those from ponds that had received the nitrogenous fertilizer treatment.

The references used in identifying benthos were by Johannsen (1935; 1936; 1937), Thomsen (1937), Pennak (1953), Edmondson (1959) and Usinger (1956).

3.2 Materials and methods

The Ekman dredge was used for part of the sampling. It sampled an area of 225 cm^2. Samples were obtained at depths of 0.6 m and 1.2 m. The bottom materials were brought to the laboratory for further processing. Those samples that could not be processed immediately were refrigerated. To separate organisms and light debris from the sand and gravel, water was poured into the sample, mixed vigorously, and then poured through a screen. This was repeated several times until no macroscopic organisms remained in the sand. By the use of the electric stimulator, the organisms were located and removed from the debris. Further examination was made to discover and remove dead individuals.

Two uses were made of multiple-plate samplers. Samplers that were composed of 9 large plates and 8 small plates, thus providing 8 protected spaces in which benthos could develop, were hung in such positions that they were approximately 0.3 m from the surface and 0.3 m from the bottom. The durations of exposure were three weeks for the first three sampling periods and one week for the last period. Before being removed from the water each sampler, with the water immediately around it, was enclosed in a plastic bag to prevent loss of loosely attached organisms. In the laboratory each sampler was dismantled in a pan and the accumulation of benthos and "aufwuchs" debris were scraped from the edges and inner surfaces. The sample was concentrated in a Foerst plankton centrifuge, and preserved in 70 percent alcohol. Later the samples were transferred to a preweighed crucible, dried in an electric oven at 60°C for 48 hours, stored in a desiccator, and weighed to obtain the dry weight of the sample. The other use of multiple-plate samplers was that described by Liang (1964). Each sampler, consisted of two large plates separated by one small plate, provided only one protected space in which benthos could develop. The contact of the bottom with the edge of each sampler allowed non-swimming and burrowing forms to have access to space between the plates. When these samplers were dismantled, the organisms were preserved, identified, and counted. All counts and weights are per m2.

3.3 Results

3.3.1 Sampling with Ekman dredge

The kinds of benthic animals found in samples obtained by the use of the Ekman dredge are listed below:

- Nematoda
    - One species
- Oligochaeta
    - Several species
- Ephemeroptera
    - *Hexagenia limbata*
    - *Caenis* sp.
- Trichoptera
    - *Leptocella* sp.
    - *Hydroptila* sp.
- Diptera
    - *Tendipes* sp.
    - *Pentaneura* sp.
    - *Bezzia* sp.
    - *Parabezzia* sp.
    - *Chrysops*

Numerically the oligochaete worms were the dominant organisms in these samples. Because of the relatively large sizes of many individuals, these worms constituted the greatest volume of potential food for fish. However the variation in abundance was so great that no distinct trends related to fertilizer treatments or rates of stocking of fish were evident.

Chironomid larvae were more abundant in Ekman samples from fertilized ponds than in those from unfertilized ponds. The numbers obtained from ponds that had received the nitrogenous fertilizer treatments were somewhat smaller than the numbers from ponds that had received the non-nitrogenous fertilizer treatment.

3.3.2 Sampling with muliple-plate samplers touching the bottom

The kinds of benthic animals found in samples obtained by the use of the multiple-plate samplers that had one edge touching the bottom are listed below:

- Coelenterata
  - *Hydra* sp.
- Turbellaria
  - *Dugesia* sp.
- Rotifera
  - *Keratella* sp.
- Nematoda
  - one species
- Ectoprocta
  - *Plumatella* sp.
- Oligochaeta
  - *Nais* sp.
  - *Paranais* sp.
  - *Pristina* sp.
  - *Naidium* sp.
  - *Chaetogaster* sp.
- Cladocera
  - *Eurycercus* sp.
- Copepoda
  - *Ectocyclops phaleratus*
  - *Bryocamptus* sp.
- Ostracoda
  - *Cyrpis* sp.
  - *Cypridopsis* sp.
- Ephemeroptera
  - *Caenis* sp.
- Odonata
  - *Somatochlora* sp.
  - *Celithemis* sp.
  - *Neurocordulia* sp.
  - *Ischnura* sp.
  - *Lestes* sp.
- Trichoptera
  - *Ochrotrichia* sp.
  - *Leptocella* sp.
  - *Hydroptila* sp.
- Coleoptera
  - *Dipneustes* sp.
  - *Berosus*
- Diptera
  - *Tendipes* sp.
  - *Pentaneura* sp.
  - *Bezzia* sp.
  - *Probezzia* sp.
- Gastropoda
  - *Gyraulus* sp.
  - *Physa* sp.
  - *Ferrissia* sp.

A comparison of the lists of organisms from the two kinds of samplers reveals that a much larger variety occurred in samples on the multiple-plate samplers than in the Ekman samples. The difference was in part the result of the Ekman sample being "screened" in the process of separating organisms from sand and debris. Some of the smaller individuals probably were lost through the screen. However, the difference in the dominance of groups is noteworthy. On the multiple-plate samplers, the chironomids made up the greatest volume of potential fish food. The damselfly naiads were not numerous, but because of the relatively large size of many of them, this group ranked second. The oligochaetes were numerous on the plates, but were less abundant and were much smaller than most of the individuals in the Ekman samples.

In samples from fertilized ponds, the chironomid larvae were more numerous than in samples from unfertilized ponds. The numbers from ponds that had received nitrogenous fertilizer were approximately the same as those from ponds that had received the non-nitrogenous fertilizer treatment. The different rates of stocking appeared to influence the numbers of chironomid larvae. The samples from ponds that received the higher rates of stocking contained the larger numbers of chironomid larvae than did those from ponds with lower stocking rates. Since animals between the plates on the samplers were not exposed to predation by fish, their relative abundance after a period of exposure is assumed to be a parameter of the productivity, which appeared to increase with the increase in the rate of stocking of fish.

The oligochaetes were more numerous in samples from fertilized ponds than in samples from unfertilized ponds, but the samples from ponds that received the nitrogenous fertilizer treatment were essentially like those from ponds that received the non-nitrogenous fertilizer treatment. The stocking rates did not appear to influence the number of oligochaetes.

3.3.3 Dry weights from multiple-plate samplers not touching bottom

These data are entirely quantitative. No separation of organisms occurred in the processing. The samplers 0.3 m from the surface and 0.3 m from the bottom were located near edges of the ponds. In this location the plates offered attractive places for oviposition by many kinds of animals. Usually the egg masses were on the upper surface of the top plate or the lower surface of the bottom plate, and for this reason were not included in the sample. However, when egg masses occurred between the plates they became part of that sample. Such factors resulted in a large amount of variation in the dry weights of samples.

Statistically there appeared to be no difference between the average dry weights from ponds that received 0-0-0 and the 8-8-2 fertilizer treatments, and no difference between the 8-8-2 and the 0-8-2 treatments. However dry weights of samples from ponds that received 0-8-2 treatment were greater than those from ponds that received 0-0-0 treatment. There was no evidence that the differences in the rates of stocking influence the dry weights.

From the studies on benthos in various kinds of samples the 0-0-0 fertilizer treatment was not as productive as was either the 0-8-2 or the 8-8-2 treatment. The 0-8-2 and 8-8-2 treatments were approximately equal in value. The 0-8-2 appeared to be the best when evaluated by dry weight method.

4 FISH

4.1 Review of literature

Evaluations of the use of nitrogen in fertilizers for production of fish in ponds have not given uniform results. The work of Swingle and Smith (1939) was mentioned in section 2.1. Lawrence (1943) reported best production when fertilizer contained nitrogen along with phosphorus and potash. Surber (1943) indicated that nitrogen played an important role in control of weeds. Hepher (1962) reported that phosphate in fertilizer was responsible for a greater increase in the weight of fish than was nitrogen. Hickling (1962) found that nitrogen in fertilizer was a poorer producer than was phosphate. Rabanal (1960) and Gooch (1962), both reporting on work done in the ponds used in this study, stated that elimination of nitrogen from the "complete" (N-P-K) fertilizer did not result in a decrease in the production of fish. Byrd and Swingle (1964) recommended that nitrogen could be eliminated from fertilizer for old, well-fertilized ponds without reducing fish yields. Tilapia mossambica have been found to feed on a wide variety of material including plankton, decomposing vegetation, filamentous algae, periphyton, benthos, and various supplemental feeds (see references cited in section 2.1). Kelly (1955) observed that in aquaria T. mossambica ceased to feed when the temperature of the water was lowered to approximately 15.5°C.

When eaten by T. mossambica, phytoplankters varied in digestibility. Vaas and Sachlan (1952) reported that Botryococcus and Microcystis were incompletely digested. Prowse (1961) reported that Anabaenopsis spp. and Oedogonium were well digested, very little Spirogyra appeared to be digested, but Microcystis, Oscillatoria and Anabaena spp. did not appear to be digested.

4.2 Materials and methods

Beginning 28 July and at four week intervals thereafter, the fish populations in each pond were sampled with a seine. Each sample was composed of 20 fish, which were weighed to the nearest g and measured to the nearest 2 mm total length. Of these, 10 were preserved in 10 percent formalin. The fish that were kept were replaced by individuals of approximately the same size. When the ponds were drained all fish were collected and separated into originally stocked individuals and their young. The final weight of fish minus the initial weight was considered as the net production. Numbers of young fish were estimated by counting the individuals in weighed samples and computing the total numbers from the weights of young fish. The relative growth rate at the time of the draining of the pond was calculated by the formula: $\frac{\text{Net production}}{\text{Initial weight}}$.

Gut contents analyses were made on the preserved fish. For freshly eaten food the contents of the anterior 2.5 cm of the gut, including the enlarged anterior end or stomach, was removed. The contents of the posterior 2.5 cm of the intestine were removed to determine the digestibility of various foods. The material obtained from each region was mixed with 10 ml of water in a dish and examined with stereoscopic and compound microscopes. The method of "frequency of occurrence" advocated by Lagler (1956), was used to evaluate food habits. The viability of plankton in faeces from fish was tested by placing faeces from one fish from each pond in 100 ml of sterilized water in a 250 ml flask and exposing these cultures to light from a window facing north. The cultures were kept for four weeks.

4.3 Results

4.3.1 Production

The production of fish in unfertilized ponds appeared to be increased by increase in rates of stocking, but results were somewhat variable. The productions in fertilized ponds increased 145 percent with the increased rates of stocking. However, the productions that resulted from the 0-8-2 fertilized treatment and those from the 8-8-2 fertilizer treatment at a given stocking rate were essentially equal. This lack of importance of added nitrogen as a component of fertilizer for these ponds agrees with the results of Rabanal (1960), Gooch (1962), and Liang (1964). The continued increase in production with increase in rate of stocking (Table II) indicated that the maximum rate of stocking used probably was not the optimum rate for maximum production of fish with the fertilizer treatments that were applied.

4.3.2 Rate of growth

The rate of growth usually decreased as the rate of stocking increased. The relative growth rates (Table II) in ponds that received the 0-0-0 fertilizer treatment were lower than in the ponds that received the 0-8-2 or 8-8-2 fertilizer treatments, but the relative growth rates that resulted from the 0-8-2 and the 8-8-2 treatments were essentially the same.

Table II

Relative growth rates of *Tilapia mossambica* from 6 July to 13-14 October in ponds that received different fertilizer treatments and different rates of stocking

Rates of stocking per ha	Fertilizer treatment 0-0-0	0-8-2	8-8-2
4,942	13.7	22.0	20.2
9,884	6.7	16.9	20.8
14,826	4.6	12.4	13.4
19,768	4.0	11.2	10.9

4.3.3 Reproduction

The production of young fish did not appear to be influenced by the rates of stocking but greater weights of young fish were produced in fertilized ponds than in unfertilized ponds (Table III).

Table III

Production of young *Tilapia mossambica* in kg per ha from 6 July to 13-14 October in ponds that received different fertilizer treatments and different rates of stocking

Rates of stocking per ha	Fertilizer treatment 0-0-0	0-8-2	8-8-2
4,942	42.7	72.2	47.3
9,884	55.3	136.4	79.7
14,826	28.7	100.6	93.4
19,768	13.7	86.5	110.4

4.3.4 Food habits

Fish obtained during July and August contained an abundance of food, but there was a decrease in, or absence of, the food-stuff in digestive systems of fish collected on 16 September and 10 October. This agreed with the observations of Kelly (1955) that *T. mossambica* ceased to feed when the water temperature was reduced to approximately 15.5°C.

The digestive tract is typical of fish that feed on detritus. There is no true stomach in the species; it is replaced by a bulb-like enlargement of the tract. The intestine is long and much coiled, and its wall is quite thin.

T. mossambica fed chiefly on detrius and phytoplankton. Of the fish examined, 91.9 percent contained phytoplankton and 89 percent contained detritus. Zooplankton served as additional food. Microcrustaceans were present in 62.9 percent of the fish. They were Cladocera of the families Sididae and Daphnidae; Copepoda of the Cyclopidae and Diaptomidae, and nauplii; and Ostracoda. From ponds that received 0-0-0 fertilizer treatment, 44.4 percent of the fish contained crustaceans, whereas from the ponds that received 0-8-2 and the 8-8-2 fertilizer treatments, 75 percent of the fish contained crustaceans. Although Varikul (section 2.3.2) found Cladocera of the family Bosminidae to be most abundant in ponds that received 0-0-0 fertilizer treatment, even in those ponds these animals were less numerous in the fish than were other crustaceans. Rotifers, chiefly *Keratella* were found in 12.3 percent of the fish examined.

Benthos, chiefly larvae of Chironomidae, was eaten occasionally. Other insects and oligochaete worms were observed less frequently. A few immature mayflies and damselflies were found. Rare items were fish fry, bryozoans and fragments of higher plants.

4.3.5 Digestibility

The volume of detritus was reduced from large in the anterior part of the gut to quite small in the posterior end. This was judged to indicate a degree of digestibility of at least part of the material. Most of the zooplankton and benthos, except the Ostracoda, was well digested.

Different kinds of phytoplankton varied in digestibility, as judged by their appearance under the microscope. *Oedogonium*, *Surirella*, *Anabaena* and *Spirulina*, appeared to be well digested. *Eudorina*, *Oocystis*, *Pediastrum*, *Microasterias*, *Staurastrum*, *Microcystis*, *Oscillatoria*, and diatoms other than *Surirella* appeared poorly digested. *Closterium* appeared to be unaffected by digestion.

4.3.6 Viability

None of the cultures of faeces from fish developed phytoplankton. However, Ostracoda occurred in every culture. Some were active almost immediately after the faeces were put into the water. Others appeared later. The numbers of these animals that passed through the digestive tracts as living adults and as viable eggs were not determined. There was no evidence that ostracods were affected by the digestive system of the fish.

5 DISCUSSION

In unfertilized ponds the rates at which fish were stocked influenced the dry weights of plankton. Although the fish fed on plankton, the harvest of plankton by fish at the highest stocking rate appeared to be more than counterbalanced by the added fertility that resulted from the presence of the fish, as the dry weight of plankton per l of sample was greatest in the pond that contained the largest number of fish. By feeding on detritus, the fish may hasten the rate of recirculation of plant nutrients in forms that are usable by plankton.

In fertilized ponds, different rates of stocking did not influence the dry weights of plankton. The dry weights of plankton in samples from the 8-8-2 ponds were usually somewhat greater than in samples from 0-8-2 ponds.

Most of the volumes of various kinds of microcrustaceans were greater in fertilized ponds than in unfertilized ponds. The volumes of Bosminidae were conspicuously greater in unfertilized ponds than in fertilized ponds. However, even in unfertilized ponds these small cladocerans were essentially unused by fish.

It was observed (i) that chironomid larvae were the dominant kind of benthos eaten by the fish and (ii) that there were greater numbers of these larvae per unit area in the protected space between plates of multiple-plate samplers than there were in standing crop samples by the Ekman sampler. These observations indicated that the fish had harvested most of the available larvae. They indicated also that when many fish are present the use of multiple-plate samplers may give a better understanding of the productivity of a body of water than is obtained by the use of the Ekman sampler. In contrast to the dry weights of plankton, the abundance of chironomid larvae appeared to be slightly greater in ponds that received non-nitrogenous fertilization than in ponds that received nitrogenous fertilization.

The rates of growth of fish were influenced greatly by fertilization, but the presence of nitrogen in the fertilizer did not increase weights of fish produced. Increased rates of stocking tilapia in unfertlized ponds gave variable results, but indicated a moderate increase in production with increased numbers of fish. In fertilized ponds increase in rates of stocking, from approximately 5,000 to 20,000 tilapia per ha, increased average net production from 341.9 to 836.7 kg per ha, an increase of 145 percent.

Although there was a considerable amount of variation in the details of the results, the data indicate that ponds that received fertilizer produced much higher yields than did the unfertilized ponds. There was no indication that the nitrogenous fertilizer treatment was superior to the non-nitrogenous fertilizer treatment for production of fish during periods while water temperature remained above 22°C.

6 REFERENCES

Ball, R.C., 1949 Experimental use of fertilizer in the production of fish-food organisms and fish. Tech.Bull.Mich.agric.Exp.Sta., (210):28 p.

Bayless, J.D., 1961 The use of electrical stimuli in live-picking organisms from bottom samples. Proc.stheast.Ass.Game Commrs, 15:286-8

Byrd, I.B., and H.S. Swingle, 1964 Pond fertilization cost can be reduced by 66 percent. Ala.Conserv., 34(3):4-6

Chen, Tung-Pai, 1953 The culture of tilapia in rice paddies in Taiwan. Fish.Ser.Chin.-Amer. Comm.rur.Reconstr., (2):29 p.

Dendy, J.S., 1956 Bottom fauna in ponds with largemouth bass only and with a combination of largemouth bass plus bluegill. Tenn.Acad.Sci., 31(3):198-207

Edmondson, W.T. (Ed.) 1959 Ward and Whipple's fresh-water biology. New York, John Wiley and Sons. Inc., 2nd Ed. 1272 p.

Gooch, B.C., 1962 Preliminary observations on the residual nature of nitrogen in ponds and its significance to fish production. Unpublished Master's thesis. Auburn University, Auburn, Alabama.

Hayne, D.W. and R.C. Ball, 1956 Benthic productivity as influenced by fish predation. Limnol.Oceanogr., 1(3):162-75

Hepher, B., 1962 Ten years research in fish ponds fertilization in Israel. The effect of fertilization on fish yields. Bamidgeh, 14(2):29-38

Hester, F.E. and J.S. Dendy, 1962 A multiple-plate sampler for aquatic macroinvertebrates. Trans.Amer.Fish.Soc., 91(4):420-1

Hickling, C.F., 1962 Fish culture. London, Faber and Faber. 295 p.

Hora, S.L. and T.V.R. Pillay, 1962 Handbook on fish culture in the Indo-Pacific region. FAO Fish.Biol.tech.Pap., (14):204 p.

Howell, H.M., 1942 Bottom organisms in fertilized and unfertilized fish ponds in Alabama. Trans.Amer.Fish.Soc., 71:165-79

Johannsen, O.A., 1935 Aquatic Diptera. Part 2. Orthorrhapha, Brachycera and Cyclorrhapha. Mem.Cornell Univ.agric.Exp.Sta., (177):1-62

__________, 1936 Aquatic Diptera, Part 3. Chironomidae: Subfamilies Tanypodinae, Diamesinae and Orthocladiinae. Mem.Cornell Univ.agric.Exp.Sta., 205:1-84

__________, 1937 Aquatic Diptera, Part 4. Chironomidae: Subfamily Chironominae. Mem. Cornell Univ.agric.Exp.Sta., (210):1-56

Kelly, H.D., 1955 Preliminary studies on Tilapia mossambica Peters relative to experimental pond culture. Proc.stheast.Ass.Game Commrs, 10:139-49

Lagler, Karl F., 1956 Freshwater fishery biology. Dubuque (Iowa), Wm.C.Brown Co., 421 p.

Lawrence, V.C., 1943 Techniques of fish pond management. Misc.Publ.U.S.Dep.Agric., (528):22 p.

Liang, J. K., Benthic fauna of fertilized and unfertilized ponds in winter. Unpublished
1964 Master's Thesis. Auburn University, Auburn, Alabama

McIntire, C. D. and C. E. Bond, Effects of artificial fertilization on plankton and
1962 benthos abundance in four experimental ponds. Trans.Amer.Fish.Soc., 91(3):303-12

Neess, John C., Development and status of pond fertilization in central Europe.
1949 Trans.Amer.Fish.Soc., 76(1946):335-58

Patriarche, M. H., and R. C. Ball, An analysis of the bottom fauna production in fertilized and unfertilized ponds and its utilization by young-of-the-year fish.
1949 Tech.Bull.Mich.St.Coll.agric.Exp.Sta., (207):35 p.

Pennak, R. W., Fresh-water invertebrates of the United States. New York, The Ronald Press
1953 Co., 769 p.

Prowse, G. A., The use of fertilizers in fish culture. Proc.Indo-Pacif.Fish.Coun., 9(2):73-5
1961

Rabanal, H. R., The effect of no fertilization and non-nitrogenous fertilization upon the
1960 chemistry of water, the plankton, bottom organisms and fish production in ponds that had received complete (N-P-K) fertilizers for the preceding 15-year period. Unpublished Doctor's Dissertation. Auburn University, Auburn, Alabama.

Surber, E. W., The effects of various fertilizers on plant growths and their probable
1943 influence on the production of smallmouth black bass in hardwater ponds. Trans.Amer.Fish.Soc., 73:377-93

Swingle, H. S. and E. V. Smith, Fertilizers for increasing the natural food for fish in
1939 ponds. Trans.Amer.Fish.Soc., 68(1938):126-35

Thomsen, L. C., Aquatic Diptera, Part 5. Ceratopogonidae. Mem.Cornell Univ.agric.Exp.Sta.,
1937 (210):57-80

Usinger, R. L., Aquatic insects of California. Berkeley and Los Angeles, Univ.of Calif.
1956 Press, 508 p.

Vaas, K.F., On the nutritional relationships between plankton and fish in Indonesian
1954 freshwater ponds. Proc.Indo-Pacif.Fish.Coun., 5(2):90-7

Vaas, K.F. and M. Sachlan, Notes on fisheries exploration of the artificial lake Tjiburuj
1952 in West Java. Contr.gen.agric.Res.Sta.Bogor., (128):1-22

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EFFECTS OF MICRO-NUTRIENTS ON THE SURVIVAL AND GROWTH OF INDIAN CARP FRY

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Abstract

Effects of micro-nutrients on the survival, growth and biochemistry of Indian carp fry from 3 to 26 days of age have been investigated. Survival is enhanced significantly by treatment with vitamin B complex, yeast, or ruminant stomach extract with cobalt nitrate. The reduction in survival due to density is significantly controlled by treatment with vitamin B complex or yeast. Among the micro-nutrient treatments employed, yeast increases growth most. Vitamin B complex and ruminant stomach extract also significantly increase growth. Based on these results, an equation for projecting yield after a specified period of time has been formulated. Yield is expressed as a function of the initial number of one-day-old fry, the proportion surviving for a given density and treatment, and the expected weight of any fish of a given species and age group. Biochemical determinations of total protein, non-protein nitrogen, acid phosphatase and alkaline phosphatase have been carried

out for untreated fry and fry treated with yeast. Treatment with yeast has a statistically significant effect on total protein and non-protein nitrogen. A significant change in total protein, acid phosphatase and alkaline phosphatase occurs with age. The significant regression of weight on total protein decreases with yeast treatment. As yeast treatment decreases the total protein per g dry weight but increases the total weight, it appears to make fry more efficient as weight gaining units.

INFLUENCE DES OLIGO-ELEMENTS SUR LE TAUX DE SURVIE ET DE CROISSANCE DES ALEVINS DE CARPE INDIENNE

Résumé

Les études ont porté sur les effets des oligo-éléments sur la survie, la croissance et la biochimie d'alevins de carpe indienne âgés de 3 à 26 jours. Le taux de survie est sensiblement amélioré par un traitement au complexe vitaminique B, à la levure ou à l'extrait d'estomac de ruminant associé à du nitrate du cobalt. La diminution du taux de survie due à la densité est sensiblement réduite par un traitement au complexe vitaminique B ou à la levure. Parmi les oligo-éléments employés, c'est la levure qui a eu l'effet le plus favorable sur la croissance. Le complexe vitaminique B et l'extrait d'estomac de ruminant ont également sensiblement amélioré la croissance. Partant de ces résultats, on a établi une équation permettant de prévoir la production après un laps de temps déterminé. Dans cette formule, la production est exprimée sous forme de fonction du nombre initial d'alevins d'un jour, de la proportion de survivants calculée pour une densité et un traitement donnés et du poids prévu d'un poisson quelconque d'une espèce donnée selon le groupe d'âge. Le dosage biochimique des protéines totales, de l'azote non protéique, de la phosphatase acide et de la phosphatase alcaline a été effectué pour les alevins non traités et les alevins traités à la levure. Du point de vue statistique, le traitement à la levure a un effet sensible sur la quantité totale de protéines et d'azote non protéique. Avec l'âge, on constate un changement notable des protéines totales, de la phosphatase acide et de la phosphatase alcaline. La régression sensible de la relation poids/protéines totales diminue lorsque les sujets sont traités à la levure. Etant donné que ce traitement a pour effet de diminuer la quantité de protéines par gramme de poids sec mais d'augmenter le poids total, il paraît rendre les alevins plus aptes à prendre du poids.

EFECTOS DE LOS MICRO-NUTRIENTES SOBRE LA SUPERVIVENCIA Y CRECIMIENTO DE LOS ALEVINES DE CARPA INDIA

Extracto

Han sido investigados los efectos de los micro-nutrientes sobre la supervivencia, crecimiento y bioquímica de los alevines de carpa india de 3 a 26 días de edad. La supervivencia se mejora notablemente mediante el tratamiento con complejo de vitamina B, levaduras o extracto de estómagos de rumiantes con nitrato de cobalto. La reducción de la supervivencia debida a la densidad se limita sensiblemente mediante el tratamiento con complejo de vitamina B o levaduras. Entre los tratamientos con micro-nutrientes empleados, las levaduras son las que determinan un crecimiento mayor. El complejo de vitamina B y los extractos de estómagos de rumiantes también aumentan notablemente el desarrollo. Basada en estos resultados se ha formulado una ecuación para proyectar el rendimiento al cabo de un determinado período de tiempo. El rendimiento se expresa como función del número inicial de alevines de un día, la proporción superviviente para una determinada densidad y tratamiento, y el peso esperado de cualquier pez de una determinada especie y grupo de edad. Se han llevado a cabo determinaciones bioquímicas de la proteína total, nitrógeno no proteínico, fosfatasa ácida y fosfatasa alcalina para alevines sin tratar y tratados con levadura. El tratamiento con esta última tiene un efecto estadísticamente sensible sobre el nitrógeno proteínico y no proteínico total. Con la edad se registra un sensible cambio en la proteína total, la fosfatasa ácida y la alcalina. La notable regresión del peso sobre la proteína total disminuye con el tratamiento de levadura. Como este tratamiento hace descender la proteína total por gramo de peso de materia seca pero aumenta el peso total, hace que los alevines sean más eficaces como unidades ganadoras de peso.

1 INTRODUCTION

The survival and growth of an individual organism are influenced by the conditions characterizing the post-embryonic period of its life. In all species, survival is initially low, that is, the probability that the individual organism will die is high. If the internal and external environment are suitably modified, the likelihood of the individual organism's surviving increases. Development undergoes an initial latent period, after which there is very rapid growth. It is possible to alter the rate of growth during this period by changing the internal and external environment. The sensitivity of the organism during this period to its environment suggests that it may be practicable to determine the optimum conditions for the desired level of survival and rate of growth.

In commercial carp [1] cultivation in India, as traditionally and generally practised, the newly hatched fish are collected at the river spawning grounds and placed in large earthen vessels. The hatchlings live in the vessels for several days during which they are taken to ponds for cultivation. After only one day in the earthen vessels, counts have shown that only ten to twenty percent of them may be expected to survive. Effects on growth can only be surmised. From the point of view of food production, it is of utmost importance to reduce the wastage of fish fry which results from these traditional practices. Efforts in this direction which have recently been made include transport of fry in oxygenated plastic bags and induced spawning of carp by pituitary injections (e.g. Barrackpore, Central Inland Fisheries Research Institute, 1958).

The Biometry Research Unit of the Indian Statistical Institute has been engaged in an intensive study of the post-embryonic period of life of Indian carp for nearly a decade. Particular attention has been devoted to the identification of micro-nutrients which will significantly increase both the growth and survival of the fry. This paper deals with the effects of micro-nutrients on survival and growth during the post-embryonic period, on projections of yield, and on the biochemistry of fry.

2 SURVIVAL OF FRY

2.1 Procedures

2.1.1 Laboratory

The laboratory contained a large number of experimental units for cultivation and observation of the fry. Each experimental unit consisted of an earthen bowl, 40 cm in diameter, which contained 9 litres of water and was covered with screening. The water of each unit was changed every 24 hours by a siphoning technique. Fresh pond water, from the same source, was added and the water maintained at the 9 litre level throughout the experiment. Temperature and pH of the water were recorded daily. Fluorescent tube lights were arranged to ensure uniform lighting throughout the laboratory 12 hours daily, and fans were arranged to keep the air circulating throughout the laboratory. Experiments were conducted yearly during the spawning season from June to August.

2.1.2 Supply and feeding of fry

Indian fresh-water carp were obtained from the river spawning grounds one day after hatching from supplies for commercial carp cultivators. The carp were brought to the laboratory on the same day in the earthen vessels in which they were supplied. They were immediately allocated to the experimental units by randomly assigning one teaspoonful of carp (containing approximately 600 carp) to each experimental unit. Exact enumeration was not possible due to the minute size of the carp.

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[1] The carps commercially cultivated in India are Catla catla, Labeo rohita and Cirrhina mrigala. In this paper these species are considered together, except where specifically mentioned.

Table I

Mean percentage survival of Indian carp fry at 11 days of age *

Treatment	Percentage survival	Initial Density	
		ml per fish	fish per litre
(1)	(2)	(3)	(4)
Untreated Control	30.33	22.68	44.09
B_{12}	45.24	21.53	46.45
RSE + $Co(NO_3)_2 \cdot 6H_2O$	60.71	22.00	45.45
$Co(NO_3)_2 \cdot 6H_2O$	49.75	24.43	40.94
B Complex	64.20	20.05	49.87
Yeast	60.24	17.72	56.44

* Based on six experiments

Table II

Expected percentage survival of Indian carp fry at 7 days of age in relation to initial density

Density as Initial Volume of Water			Density as Initial Number of Fish		
	percentage survival			percentage survival	
ml per fish	untreated control	B complex treatment	fish per litre	untreated control	B complex treatment
(1)	(2)	(3)	(4)	(5)	(6)
10	15.31	51.59	10	59.45	90.36
20	26.06	67.73	20	45.03	83.39
30	34.02	75.63	30	36.24	77.43
40	40.16	80.30	40	30.32	72.26
50	45.02	83.40	50	26.06	67.73
60	48.99	85.60	60	22.85	63.74
70	52.27	87.24	70	20.35	60.20
80	55.04	88.51	80	18.34	57.03
90	57.40	89.53	90	16.69	54.18
100	59.45	90.36	100	15.31	51.59
110	61.23	91.05	110	14.15	49.25
120	62.80	91.63	120	13.14	47.10
130	64.19	92.13	130	12.27	45.14
140	65.43	92.56	140	11.51	43.33
150	66.55	92.95	150	10.84	41.66
160	67.56	93.28	160	10.24	40.12
170	68.48	93.57	170	9.71	38.68
180	69.31	93.84	180	9.22	37.35
190	70.08	94.08	190	8.79	36.10
200	70.78	94.30	200	8.39	34.94

Following the Government of India recommended cultural practices for Indian carp fry (Chopra, 1951), the carp were fed live Daphnia cultivated in a richly fertilized pond. Each experimental unit received 10 ml of a solution of five parts Daphnia by volume to 95 parts of water daily. This ration was considered sufficient as some Daphnia always remained unconsumed.

2.1.3 Micro-nutrients

The effects of five micro-nutrients were studied. The micro-nutrients and their daily dosage levels are as follows:

i) B_{12}: crystalline vitamin B_{12}, 25 µg; British Drug Houses Ltd.

ii) RSE + $Co(NO_3)_2 . 6H_2O$: ruminant stomach extract, 10 ml, and cobalt nitrate, 1 µg. The ruminant stomach extract consisted of the juice expressed from the entire contents of the four stomachs of a freshly slaughtered goat; no further water was added. The cobalt nitrate was obtained in powder form and dissolved in distilled water. The molarity was 3.43×10^{-6} and total impurities present did not exceed 0.045 percent.

iii) $Co(NO_3)_2 . 6H_2O$: cobalt nitrate, 1 µg.

iv) B complex: vitamin B complex, one tablet containing 10 mg thiamine hydrochloride, 3 mg riboflavin, 2 mg pyridoxine hydrochloride, 15 mg nicotinic acid amide, and 3 mg calcium pantothenate; Teddington Chemical Factory, Bombay.

v) Yeast: dried brewer's yeast, one tablet containing 0.324 g yeast (prior to 1963) or 0.5 g yeast (1963 onwards); British Drug Houses Ltd.

2.1.4 Collection of survival data

To obtain the survival data, the dead carp were completely enumerated for each experimental unit daily. The dead carp settled to the bottom of the experimental unit after a centrifugal current was induced in the water, and were withdrawn with a glass pippette, placed on blotting paper and counted. A fresh pippette was used for each experimental unit each day. At the end of the experiment, the live carp were counted and the number initially placed in the experimental units was reconstructed by adding the total number dead to the number alive at the end of the experiment.

2.2 Statistical design

Randomized block designs were employed for each experiment. Using a randomized block design, the experimental units were placed in blocks and randomly assigned to the several treatments. This design permits a test of the significance of block effects (indicating position within the laboratory) as well as treatment effects and distributes the treatments randomly throughout the laboratory. Tests of significance were carried out by analysis of variance (Cochran and Cox, 1957).

2.3 Results: Percentage survival

Table I presents the mean percentage surviving (column (2)) under the different micro-nutrient treatments, along with the mean initial density of the fry, in terms of ml water per fish (column (3)) and number of fish per litre (column (4)). The value of 30.33 percent for the untreated control is comparable to figures reported for carp nurseries (Barrackpore, Central Inland Fisheries Research Institute, 1962). For marine nurseries, Halliday (1965) has reported 52 percent survival. Treatment with certain micro-nutrients significantly enhances survival over that of the untreated control. Sixty percent survive with vitamin B complex,yeast, or ruminant stomach extract with cobalt nitrate. Some increase in survival also occurs with vitamin B_{12} and with cobalt nitrate. It was hypothesized that the cobalt nitrate permitted synthesis of vitamin B_{12} by the fry, either from their regular diet or from the ruminant stomach extract (Das, 1959; 1960 a, b; 1965 b; Das and Krishnamurthy, 1959).

2.4 Results: Density

The effect of density on survival has been widely observed (Lack, 1954; Andrewartha and Birch, 1954); increasing density being associated with decreasing survival. The density-survival relationship for Indian carp fry was characterized mathematically for the first time by Das (1961 a). A hyperbolic equation $Y = 100(\frac{Z}{X}) = \frac{100}{a + bX}$ with Y = percentage survival, Z = number surviving, X = initial number, and a and b being the fitted constants, characterizes the density-survival relationship during the post-embryonic period of life. For the hyperbolic equation fitted to the effect of density on survival of untreated control carp at the end of the first week, $a = 1.1434$ and $b = 0.0060$. Similarly, for carp treated with vitamin B complex, $a = 1.0143$ and $b = 0.0010$. Comparison of the values for the constant a shows that vitamin treatment immediately enhanced survival. Comparison of the values of the constant b shows that vitamin B complex alleviated the effect of density on survival. These results are illustrated by Table II. Expected percentage survival, computed from the hyperbolic equation, is reported in terms of density as initial volume of water available per fish as well as initial number of fish per litre of water. Expected values for treated and untreated control carp show that at low density, and even more at high density, vitamin B complex treatment enhances survival.

2.5 Discussion

Results of experiments conducted in earthen bowls, which simulate equipment used by commercial carp cultivators, show that micro-nutrients can enhance survival and reduce the effect of density. It should be noted that even at very low densities, treated carp are more likely to survive than untreated carp. Projected values for the effects of such treatment on a large scale will be presented in section 4.

3 GROWTH OF FRY

3.1 Post-embryonic growth

3.1.1 Collection of data

Laboratory, supply and feeding of fry and micro-nutrients have been described in sections 2.1.1, 2.1.2, and 2.1.3. Growth data were collected by withdrawing and weighing samples consisting of ten living fry daily from the experimental units. Samples were withdrawn from half of the replications for all treatments on even-numbered days of age and from the other half on odd-numbered days of age. Each experimental unit was sampled every other day throughout the experimental period. Samples were kept separate from each other throughout the drying and weighing process so that weight data would be available for individual experimental units.

The drying and weighing procedure followed the same time schedule every day. After being withdrawn from an experimental unit, a sample of ten fry was placed in 70 percent alcohol and then the ten fry were dried separately on blotting paper. After this, the sample was placed in a drying chamber at 32°C for six hours and then at 60°C for the next 18 hours. It was then placed in a dessicator for one hour, after which it was immediately weighed on a chemical balance.

3.1.2 Results

Table III gives the dry weight per individual carp fry at 3, 11, and 19 days of age under different micro-nutrient treatments. The initial equivalence of the fry is illustrated by column (2). While at 11 days the fry still are nearly equal in weight, by 19 days of age clear differences ($P < 0.01$) are apparent. In the order of effect on growth rate, from most to least effective, the micro-nutrients are yeast, vitamin B complex, ruminant stomach extract with cobalt nitrate, and vitamin B_{12}. These results suggest that i) vitamin B_{12} is not a carp growth factor, ii) yeast contains a growth factor not present in standard preparations of vitamin B complex, and iii) ruminant stomach extract with cobalt nitrate has an effect not unlike that of vitamin B complex. The results of this and other experiments (Das, 1960 b, 1965 b) support the hypothesis that growth in the post-embryonic period of life can be enhanced when the internal and external environment are modified by micro-nutrients. Furthermore, results with varying yeast dosage levels (Das, 1965 b) suggest that growth is enhanced by the protein added to the diet by yeast.

3.2 Juvenile growth

3.2.1 Collection of data

Three ponds on the premises of the Indian Statistical Institute were used for this investigation. Two months before the fish were to be placed in the ponds, all fish present were removed and the water was fertilized with mahua seed cakes. The length, width, and depth, in meters, of the three ponds were 46.0, 27.5, and 4.5; 26.0, 24.5, and 4.0; and 27.5, 23.0, and 4.0 respectively.

Three hundred fry each of *Catla catla* and *Labeo rohita* were placed in each of the ponds when they were twenty days old. No additional food, beyond that existing naturally in the ponds, was given after the fish were introduced. To obtain the growth rate data, samples of fish were withdrawn for weighing at regular intervals throughout a two-year period. A sample was defined as all fish obtained in the first two nettings of a pond. Each fish caught was weighed individually on an accurate balance and put back in the pond (Das, 1960c).

3.2.2 Results

Table IV gives the mean weights in grams of *Catla catla* and *Labeo rohita* specimens according to age. A mean weight may be interpreted as the expected weight for an individual fish. Using mean wet weights for the post-embryonic period and the mean weights of Table IV, linear equations have been fitted to age in days. The fitted equations are: $W'_c = -12.0880 + 1.3682\,a$ for *Catla catla* and $W'_r = 16.1597 + 0.2596\,a$ for *Labeo rohita*, where W' = expected weight in grams and a = age in days. The more rapid growth of *Catla* is illustrated by these equations and also by the values reported in Table IV. The equations permit projections of yield which will be discussed in section 4.

3.3 Discussion

The results reported in Table III demonstrate that micro-nutrients enhance the growth of Indian carp fry. As the growth of domesticated avian and mammalian species has also been found to be enhanced by micro-nutrients, particularly vitamins, this result is not unexpected. The present contribution is in identifying the effective micro-nutrients and their optimum dosage levels, with particular attention to feasibility for commercial carp cultivation. In the experiment reported in Table III, fry treated with yeast weighed the most. While yeast, vitamin B complex and ruminant stomach extract with cobalt nitrate were equally effective in enhancing survival, yeast was superior to vitamin B complex and the extract in increasing growth. Yeast shares the survival-promoting and density-controlling factors of vitamin B complex and the extract, and in addition contains a growth-promot-

Table III

Mean dry weight in milligrams of Indian carp fry at 3, 11, and 19 days of age *

Treatment	Age in Days		
	3	11	19
(1)	(2)	(3)	(4)
Untreated Control	0.1900	0.2100	0.3467
B_{12}	0.1867	0.2200	0.8900
RSE + $Co(NO_3)_2$	0.1933	0.2233	1.0400
B Complex	0.1900	0.2300	1.2167
Yeast	0.1867	0.2333	1.6500

* Based on one experiment with 6 replications

Table IV

Mean wet weight in grams at known age of the Indian carp *Catla catla* and *Labeo rohita* reared in ponds

Age in days	*Catla catla*	*Labeo rohita*
(1)	(2)	(3)
50	103.48	58.12
81	103.48	55.28
111	110.57	59.54
142	190.80	66.06
172	193.63	70.88
202	158.76	89.30
231	377.06	56.70
261	357.21	91.57
294	388.40	88.74
322	450.76	123.89
353	529.29	199.30
385	509.45	77.96
414	558.50	175.77
448	603.86	148.27
476	686.07	189.09
491	664.24	192.78
506	709.60	138.92
522	676.71	172.08
538	700.24	157.91
553	705.06	161.60
566	752.69	109.15
596	789.55	93.56
627	846.25	114.82

ing factor. The dosage employed has been 0.5 g per 9 litres, approximately 56 mg per litre of water. This dosage can be economically and easily administered in large-scale carp cultivation. Some projections of the yield which might be expected by implementation of yeast treatment at the post-embryonic stage are discussed in section 4.

Observations on the growth of pond-reared fry have been summarized in Table IV. The conditions of cultivation were those typically encountered in commercial carp cultivation in the region around Calcutta, India. The observations may reflect the usual pattern of growth. It may be noted that growth studies on Indian carp are generally based on catches from rivers, and hence the results may not reflect the pattern of growth in ponds. Finally, it may be mentioned that the results in Table IV are for carp of known age and not age as inferred from scale readings or length-frequency distributions.

4 PROJECTIONS OF YIELD

Yield of any crop depends on two basic components, the number of productive units and the values of the productive units (Das, 1963). In the context of fisheries, the number of productive units is the number of fish of a given species and age group, and the values of the productive units are their weights. The expected value for any productive unit taken at random is the mean of the weights. Yield is defined as the total wet weight of the catch of a given species and age group, and can be regarded as the product of the number of fish and the expected weight of any fish taken at random, i.e., the mean weight of all fish in the catch.

The data presented in the preceding sections provide information about both the number of fish and their expected weight. Section 2 describes the effects of density and vitamin treatment on the number of fish, and section 3 presents expected values for pond-reared fish of two species at varying ages. These findings permit a more detailed statement of the components of yield. Let

$$Y(t/n_o, d, Tr) \qquad [1]$$

be the true yield after a time period t, given the initial number n_o, density d and treatment Tr in the post-embryonic period, and let

$$Y'(t/n_o, d, Tr) \qquad [2]$$

be its estimate. Then

$$Y'(t/n_o, d, Tr) = (n_o \cdot p_{d, Tr})\bar{w}_{t, Tr} \qquad [3]$$

when

n_o is the initial number of one-day-old fry,

$p_{d,Tr}$ is the proportion surviving under specified density and treatment in the post-embryonic period, and

$\bar{w}_{t,Tr}$ is the mean weight after time period t for all fish receiving treatment Tr.

Table V gives projected values of $Y'(t/n_o, d, Tr)$ at $t = 1$ year for $n_o = 100{,}000$, using the values of $p_{d, Tr}$ and $\bar{w}_{t,Tr}$ from Tables II and IV. In Table V, percentage survival at 7 days gives $100p_{d,Tr}$. For $t = 1$ year and $Tr = 0$ (untreated control), Table IV gives $\bar{w}_{t, Tr} = 0.49$ kg for Catla catla and $\bar{w}_{t, Tr} = 0.11$ kg for Labeo rohita, which are the values used to compute $Y'(t/n_o, d, Tr)$ shown as kg wet weight yield.

Table V

Effect of density and treatment in the post-embryonic period on the estimated yield in kg of one-year-old Indian carp reared in ponds

100,000 One-day-old Fry							
Measure	Treatment	Untreated control			Yeast treatment		
	density	10 ml/fry	40 ml/fry	100 ml/fry	10 ml/fry	40 ml/fry	100 ml/fry
(1)		(2)	(3)	(4)	(5)	(6)	(7)
Percentage survival at 7 days		15.31	40.16	59.45	51.59	80.30	90.36
Yield *Catla catla* at 1 year		7,461	19,570	28,970	25,140	39,130	44,032
Yield *Labeo rohita* at 1 year		1,698	4,454	6,593	5,721	8,905	10,021

Table VI

Mean biochemical values for Indian carp fry treated with 0,0.5 and 2.0 g yeast daily

Age in days	Total protein (g)			Nonprotein nitrogen (mg)			Acid phosphatase (KA Units)			Alkaline phosphatase (KA Units)		
	0g	0.5g	2.0g	0g	0.5g	2.0g	0g	0.5g	2.0g	0g	0.5g	2.0g
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
15	.0014	.0013	.0013	.0213	.0397	.0277	.0240	.0317	.0333	.0433	.0483	.0617
16	.0010	.0014	.0013	.0503	.0550	.0783	.0123	.0483	.0473	.0317	.0467	.0667
17	.0016	.0012	.0028	.0550	.0770	.0843	.0223	.0460	.0690	.0283	.0480	.0807
18	.0014	.0020	.0019	.0330	.0330	.0587	.0147	.0160	.0480	.0133	.0233	.0513
19	.0014	.0017	.0021	.0183	.0660	.0513	.0247	.0350	.0383	.0423	.0733	.0517
20	.0012	.0014	.0016	.0257	.0330	.0403	.0217	.0373	.0600	.0327	.0493	.0547
21	.0016	.0023	.0031	.0183	.0403	.0403	.0617	.0360	.0370	.0333	.0567	.0600
22	.0016	.0029	.0023	.0553	.0533	.0313	.0200	.0607	.0950	.0443	.0710	.0950
23	.0017	.0029	.0035	.0440	.0953	.0917	.0567	.1917	.1233	.0400	.0967	.1600
24	.0019	.0017	.0035	.0367	.0660	.1063	.0217	.0720	.0917	.0283	.0933	.1383
25	.0021	.0014	.0046	.0587	.0330	.0660	.0227	.0480	.0337	.0387	.0543	.0663
26	.0017	.0020	.0031	.0440	.0513	.0697	.0290	.0493	.0680	.0300	.0287	.0477

The effects of density and of treatment in the post-embryonic period on projections of yield after one year are illustrated by the values in Table V. At high density (10 ml/fry), yeast or vitamin treatment triples projected yield. At medium density (40 ml/fry), treatment doubles projected yield, and increases it by a lower factor at low density (100 ml/fry). If density cannot be reduced, yeast or vitamin treatment increases survival, hence Pd, Tr yield. Without treatment, reduction in density from 10 ml/fry to 40 ml/fry nearly triples projected yield, and reduction from 10 ml/fry to 100 ml/fry nearly quadruples projected yield. The detrimental effects of density on survival are greatly reduced by yeast or vitamin treatment, and for treated fry, a change in density from 10 ml/fry to 100 ml/fry does not even double projected yield.

Equation [3] is a simplified statement of the factors entering into yield. It does, however, make explicit the role of post-embryonic conditions in projections of yield at a later date, and is based entirely upon experimental and observational results. It assumes no further reduction in survival after the post-embryonic period and hence will overestimate yield to the extent that predators and other environmental factors are hostile to the fish being cultivated.

As used in Table V, $\bar{w}_{t,\,Tr}$ has only been computed for pond-reared fish not treated with vitamins at the post-embryonic stage ($Tr = 0$). The results given in Table III suggest that growth is also affected by yeast treatment. If it can be demonstrated that $\bar{w}_{t,\,Tr}$, at $t = 1$ year, differs significantly for treated ($Tr = 1$) and untreated ($Tr = 0$) fry, then values of $Y'(t/n_o, d, Tr)$ can be computed for both sets of values of $\bar{w}_{t,\,Tr}$. Further investigations are underway in this laboratory to determine whether or not post-embryonic treatment affects $\bar{w}_{t,\,Tr}$ at a later date.

The importance of the post-embryonic period for yield of fish as a commercial crop has been shown by equation [3]. From the point of view of commercial pond fish culture, neglect of the fry at the post-embryonic period is clearly wasteful. From a purely biological point of view, investigations to determine $p_{d,\,Tr}$ and $\bar{w}_{t,\,Tr}$ under varying conditions and for various species, should be of interest, but in turn could also have practical value.

5 MICRO-NUTRIENTS AND BIOCHEMISTRY OF FRY

5.1 Procedures

5.1.1 Laboratory

Laboratory and supply and feeding of fry have been described in sections 2.1.1 and 2.1.2.

5.1.2 Micro-nutrients

Biochemical investigations have been carried out for fry treated with 0.5 and 2.0 g yeast (British Drug Houses Ltd.) daily. The untreated control is designated as 0 g yeast.

5.1.3 Biochemical determinations

Samples of fry were dried and weighed according to the procedure described in section 3.1.1. Each sample consisting of ten fry was treated separately in the biochemical analysis. A dried and weighed sample of fry was crushed with mortar and pestle, dissolved in 10 ml distilled water, and centrifuged at 2500 rpm for 10 minutes. Ten ml of the supernatant fluid was analysed for total protein, non-protein nitrogen, acid phosphatase and alkaline phosphatase, using standard laboratory methods (King and Wooten, 1956). The

Table VII

Biochemical values per g dry weight for Indian carp fry treated with
0, 0.5, and 2.0 g yeast daily

Age in days	Total protein (g)			Nonprotein nitrogen (mg)			Acid phosphatase (KA Units)			Alkaline phosphatase (KA Units)		
	0g	0.5g	2.0g	0g	0.5g	2.0g	0g	0.5g	2.0g	0g	0.5g	2.0g
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
15	0.67	0.41	0.34	10.03	11.78	7.79	11.24	10.19	8.83	20.45	14.59	16.59
16	0.44	0.40	0.32	22.33	19.25	18.15	5.27	12.83	11.26	13.33	11.92	16.30
17	1.05	0.27	0.77	35.39	17.70	22.18	15.00	10.50	17.75	17.73	11.05	20.29
18	0.69	0.63	0.52	15.93	10.08	15.68	7.10	5.01	11.02	7.04	7.20	12.84
19	0.54	0.42	0.47	6.88	16.45	11.13	8.68	9.39	8.18	15.79	17.64	11.28
20	0.58	0.44	0.34	6.04	9.82	8.81	11.22	10.83	12.59	15.91	13.98	12.29
21	0.72	0.59	0.57	7.20	8.80	7.94	31.32	8.20	7.40	13.77	12.28	10.92
22	0.60	0.73	0.36	21.12	15.28	4.98	7.32	14.50	14.63	17.22	19.44	15.15
23	1.03	0.63	0.71	25.69	19.28	20.07	33.54	39.16	23.38	23.35	19.73	32.39
24	1.28	0.62	0.72	25.85	23.69	19.08	14.39	25.49	20.36	20.73	35.63	27.30
25	1.38	0.42	1.01	46.03	9.52	14.70	13.69	15.35	6.92	26.38	14.59	14.70
26	0.88	0.42	0.51	22.67	11.63	11.05	13.53	10.76	9.62	15.66	6.25	6.68

Table VIII

Prediction of dry weight for Indian carp fry
by biochemical determinations

Yeast treatment	Multiple correlation coefficient	Standard partial regression coefficients			
		Total protein	Nonprotein nitrogen	Acid phosphatase	Alkaline phosphatase
(1)	(2)	(3)	(4)	(5)	(6)
0g	+0.7417**	-0.5423**	-0.1818	-0.0973	-0.0829
0.5g	+0.4651	-0.3434*	-0.3159*	+0.3179	-0.1705
2.0g	+0.3236	-0.0786	-0.2258	+0.2151	-0.1306

Yeast treatment	Multiple regression equation				
		regression coefficients			
	Constant	Total protein	Nonprotein nitrogen	Acid phosphatase	Alkaline phosphatase
(1)	(2)	(3)	(4)	(5)	(6)
0g	0.00310019	-0.00085347	-0.00000620	-0.00000449	-0.00000565
0.5g	0.00508884	-0.00166714	-0.00004085	+0.00003068	-0.00001584
2.0g	0.00554347	-0.00043875	-0.00004484	+0.00003741	-0.00002177

** $P < 0.01$ * $P < 0.05$

biochemical determinations were recorded in g/ml for total protein, mg/ml for non-protein nitrogen, and KA units/ml for acid phosphatase and alkaline phosphatase. By dividing each biochemical value by the dry weight in g, the base of the unit of measurement was changed from one ml to one g dry weight. Conversion of the values was necessary to permit comparison of samples differing in weight.

5.2 Statistical design and analysis

A set of six latin-squares, with each experimental unit being represented only once in one latin-square, was designed (Cochran and Cox, 1957). Each latin-square had three rows and three columns. The three treatments were replicated three times in each latin-square, with any one treatment assigned only once to any row or column. This design permitted statistical control of position effects within the laboratory on experimental data. Effects of treatment and age, within a six-day period, could be statistically examined by the analysis of variance. The experiment was conducted for 24 days, permitting the set of six latin-squares to be replicated four times. Fry were tested daily from 3 to 26 days of age. Analyses of variance were carried out to test the significance of the effects of treatment, age, rows, and columns. The analyses were carried out separately for total protein (g/g dry weight), non-protein nitrogen (mg/g dry weight), acid phosphatase (KA units/g dry weight), and alkaline phosphatase (KA units/g dry weight). The matrix of correlation coefficients for the four biochemical determinations and weight was computed separately for 0, 0.5, and 2.0 g yeast treatment groups. For each of the three matrices so obtained, multiple regression equations were computed for the prediction of weight by the four biochemical determinations.

5.3 Results

5.3.1 Analysis of variance

Table VI gives the means for the four biochemical determinations for Indian carp fry from 15 to 26 days of age according to yeast treatment. For the last set of six latin-squares (age 21 to 26 days), the results of the analyses of variance can be briefly summarized as entries in the two-way table below:

Value per carp fry		Age effect significant?	
		yes	no
Treatment effect significant?	yes	acid phosphatase alkaline phosphatase	total protein dry weight
	no	x	non-protein nitrogen

Table VII presents the means for the biochemical values per g dry weight. The results of the analyses of variance for these values in the last set of six latin-squares can also be summarized as entries in a two-way table.

Value per g dry weight		Age effect significant?	
		yes	no
Treatment effect significant?	yes	total protein	non-protein nitrogen
	no	acid phosphatase alkaline phosphatase	x

The differences between these two-way tables can be attributed to the relationships between dry weight and the biochemical determinations. The treatment effect on acid phosphatase and alkaline phosphatase can be attributed to the influence of dry weight; when that influence is partialled out, only the age effect remains significant. Similarly, total protein per fish does not change significantly with age, but when the influence of dry weight is partialled out, age is found to significantly affect total protein. Non-protein nitrogen per carp fry is apparently unaffected by age or treatment; partialling out the influence of dry weight reveals that non-protein nitrogen is affected by treatment but not by age. Age, in these analyses, refers to changes during a six-day period, which is characterized by rapid growth in carp fry.

5.3.2 Multiple regression analysis

The preceding analyses of variance compare the effects of the micronutrients and age on one biochemical determination at a time. Subsequent discussion will deal with multiple regression analysis of the biochemical determinations (Walker and Lev, 1953). The objective of the analysis is to determine the regression of dry weight, which may be interpreted as net yield, on the four biochemical determinations. This analysis has been carried out separately for the three levels of micro-nutrient treatment to determine whether treatment alters the regression on the biochemical factors. Table VIII gives the standard partial regression coefficients, multiple correlations, and multiple regression equations for the prediction of yield, as dry weight. The standard partial regression coefficients are pure numbers which indicate the regression on each biochemical factor taken by itself, for yield, after partialling out the influence of the other factors. The relative contribution of each factor, compared with other factors and under different treatments, is shown by the standard partial regression coefficients. For these data, total protein is most important under 0 g ($P<0.01$) and 0.5 g ($P<0.05$) yeast treatment, but is not statistically significant under 2.0 g yeast treatment. Non-protein nitrogen is important ($P<0.05$) under 0.5 g yeast treatment. These results suggest that, among the four biochemical factors, total protein per g dry weight, is most related to yield under untreated control conditions, but its relationship decreases with yeast treatment. The negative sign of the total protein regression coefficient means that, the greater the weight, the smaller the total protein per g weight. The multiple correlation coefficient is significant only for the untreated control, which indicates that the regression of dry weight on the four biochemical determinations is significantly altered by yeast treatment. Multiple regression equations for the prediction of yield, as dry weight, for Indian carp fry 15 to 26 days of age, are also given in Table VIII.

5.4 Discussion

Four biochemical factors which may underly yield have been explored: total protein, non-protein nitrogen, acid phosphatase and alkaline phosphatase. Total protein refers to the body protein and non-protein nitrogen measures the product of tissue metabolism and protein digestion. Acid and alkaline phosphatase are esterases involved in digestion and respiration; their optimum pH values are 5 for acid phosphatase and 9 for alkaline phosphatase. By means of the analysis of variance, the effects of micro-nutrients and age on each biochemical factor have been tested, and by means of multiple regression analysis, the regression of yield on the biochemical factors has been explored. The original biochemical determinations, expressed in terms of ml, were converted to the unit of measurement per g dry weight. Statistically significant relationships between the biochemical factors and age and weight for Indian carp fry 15 to 26 days old can be summarized as follows:

Biochemical determination per g dry weight	Yeast treatment					
	0g		0.5g		2.0g	
	age	weight	age	weight	age	weight
Total protein	increase	decrease	increase	decrease	increase	zero
Non-protein nitrogen	irregular	zero	irregular	decrease	irregular	zero
Acid phosphatase	increase	zero	increase	zero	increase	zero
Alkaline phosphatase	increase	zero	increase	zero	increase	zero

It has been demonstrated that the micro-nutrients have a statistically significant effect on dry weight, and on total protein and non-protein nitrogen per g dry weight. In the latter two cases, the nature of this effect is to reduce the amount as compared with the untreated control. The regression of weight on total protein is greatest in the untreated control, and decreases with micro-nutrient treatment, to nil in 2.0 g yeast treatment (see Table VIII). These results suggest that micro-nutrient treatment makes the fish more efficient as a productive unit, i.e., it requires less total protein and removes less non-protein nitrogen per g dry weight. This may be important in considering the merits of micro-nutrient treatment at the initial stage in pond fish culture.

The effect of age, within the narrow period of rapid post-embryonic growth, is important in considering the biological basis of fish culture. Moving averages computed for the data in Table VII show that total protein, acid phosphatase and alkaline phosphatase increase with age, and may be regarded as biochemical concomitants or correlates of growth. While non-protein nitrogen changes significantly with age, the pattern of change is irregular. This experiment constitutes the first published effort on the biochemistry of Indian carp fry. The biochemistry of the blood and serum has also been investigated for juvenile Indian carp (Das, 1961 b; 1965 a). Further biochemical experiments are in progress in this laboratory which have as their dual objective the increasing of yield and determining the mechanisms of growth in the post-embryonic period.

6 REFERENCES

Andrewartha, H.C. and L.C. Birch, The distribution and abundance of animals. Chicago,
1954 University of Chicago Press, 782 p.

Barrackpore, Central Inland Fisheries Research Institute, Rep.cent.Inld.Fish.Res.Inst.,
1958 Barrackpore, 1957-1958

__________, Rep.cent.Inld.Fish.Res.Inst., Barrackpore, 1961-1962
1962

Cochran, W.G. and G.M. Cox, Experimental designs. 2nd Ed. New York, John Wiley, 611 p.
1957

Chopra, B.N., (Ed.), Handbook of Indian fisheries. New Delhi, Ministry of Agriculture,
1951 129 p.

Das, B.C., Comparative effects of vitamin B_{12}, cobalt nitrate and ruminant stomach extract
1959 on the survival rate of Indian carp during the first three weeks of life.
Indian J.Fish., 6(1):211-21

__________, Effectiveness of yeast, vitamin B_{12}, and alternative treatments on survival
1960a of Indian carp during the early period of life. Canad.J.Biochem.Physiol.,
38(5):453-8

__________, Differential growth and survival of post-embryonic carp under treatments
1960b with yeast and vitamin B complex. J.exp.Zool., 144(2):159-64

__________, Growth rates of Catla catla and Labeo rohita in confined waters. Sci.Cult.,
1960c 26(2):94-6

__________, Effect of density on survival of Indian fresh-water carp during the first
1961a two weeks of life. Proc.nat.Inst.Sci.India, 27B(3):91-103

__________, A comparative study of the blood biochemistry of several species of Indian
1961b carp. Trans.Amer.Fish.Soc., 90(1):1-5

__________, Effects of β-napthoxyacetic acid on tillering and grain production in rice.
1963 Bot.Gaz., 124(4):270-4

__________, Age-related trends in the blood chemistry and hematology of the Indian carp
1965a (Catla catla). Gerontologia, 10(1):47-64

__________, Yeast dosage level and the post-embryonic survival and growth of the carp
1965b Labeo rohita (Ham.). J.exp.Zool., 159(3):405-12

Das, B.C. and H. Krishnamurthy, Comparative effects of yeast, vitamin B complex and vitamin B_{12} on the survival rate of Indian minor carp during the first two weeks of life. Proc.nat.Inst.Sci.India, 25B(6):300-6
1959

Halliday, R., Five acres of fish. New Scient., 27(455):330-1
1965

King, E.J. and I.D.P. Wooten, Microanalysis in medical biochemistry. 3rd Ed. London,
1956 J. and A. Churchill. 292 p.

Lack, D., The natural regulation of animal numbers. Oxford, Clarendon Press. 343 p.
1954

Walker, H. and J. Lev., Statistical inference. New York, Holt, Rinehart and Winston.
1953 510 p.

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PHYSIOLOGICAL SIGNIFICANCE OF CARBON SOURCES IN FERTILIZED FISH PONDS

by

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Abstract

The sources of carbon, especially from the standpoint of biological production, are discussed. There are certain cases where carbon sources become a limiting factor in the growth of phytoplankton. In such cases phytoplankton absorbs N and P excessively. The adequate composition of C-N-P of phytoplankton is approximately 50 : 7 : 1 by weight. Acetic acid is the only organic acid available for phytoplankton in the presence of CO_2. Favourable results were obtained by the application of acetic acid with inorganic fertilizers. The author found that high alkalinity exerts a favourable influence on the production of zooplankton.

It is assumed that organic matters in bottom soil quickly decompose at higher C-N ratios, eventually to raise alkalinity and the productivity of water.

As is seen from the favourable effects upon zoo- and phyto-plankters and bacteria, alkalinity has physiological importance not only to primary products but also to all organisms in the food chain. It is closely connected with the turnover rate of materials in fish ponds.

II/E-14

IMPORTANCE PHYSIOLOGIQUE DES SOURCES DE CARBONE DANS LES ETANGS PISCICOLES FERTILISES

Résumé

L'auteur passe en revue les sources de carbone, notamment sous l'angle de la production biologique. Dans certains cas, les sources de carbone peuvent devenir un facteur limitatif de la croissance du phytoplancton et celui-ci alors absorbe des quantités excessives de N et P. La composition adéquate en C-N-P du phytoplancton est d'environ de 50 : 7 : 1, en poids. L'acide acétique est le seul acide organique que le phytoplancton puisse assimiler en présence de CO_2; de bons résultats ont été obtenus en incorporant de l'acide acétique aux engrais inorganiques. L'auteur a constaté qu'une forte alcalinité exerce une influence favorable sur la production de zooplancton. Il est supposé que les matières organiques contenues dans le sol du fond de l'étang se décomposent rapidement lorsque le rapport C-N est élevé, ce qui a pour effet en définitive d'augmenter l'alcalinité et la productivité des eaux.

Comme le montre les effets favorables sur les zooplanctontes, les phytoplanctontes et les bactéries, l'alcalinité a une importance physiologique non seulement pour les produits primaires mais aussi pour tous les organismes de la chaîne alimentaire. Le taux d'utilisation des matériaux de l'étang est étroitement lié au degré d'alcalinité.

IMPORTANCIA FISIOLOGICA DE LAS FUENTES GENERADORAS DE CARBONO EN LOS ESTANQUES PISCICOLAS FERTILIZADOS

Extracto

Se examinan las fuentes generadoras de carbono,especialmente desde el punto de vista de la producción biológica. Existen ciertos casos en que las fuentes generadoras de carbono constituyen un factor limitante en el desarrollo de fitoplancton. En tales casos el fitoplancton absorve N y P con exceso. La composición adecuada de C-N-P en el fitoplancton es aproximadamente 50 : 7 : 1, en peso. El ácido acético es el único ácido orgánico disponible para el fitoplancton en presencia de CO_2. Se obtuvieron resultados favorables mediante la aplicación de ácido acético con fertilizantes inorgánicos. El autor comprobó que la elevada alcalinidad ejerce una favorable influencia en la producción de zooplancton.

Se supone que las materias orgánicas del fondo del suelo se descomponen fácilmente cuando las proporciones de C-N son elevadas y, eventualmente, aumentan la alcalinidad y la productividad del agua.

Como puede verse de los favorables efectos en los consumidores de zooplancton y de fitoplancton y en las bacterias, la alcalinidad tiene importancia fisiológica no solamente para los productos primarios sino también para todos los organismos de la cadena alimentaria. Está estrechamente relacionada con el coeficiente de renovación de materiales en los estanques piscícolas.

1 INTRODUCTION

The techniques of fertilized fish farming are covered by many detailed reports. This paper deals with the problems of the sources of carbon from physiological and biological production standpoint.

2 SOURCES OF INORGANIC CARBON

Inorganic carbon is available in inland waters in the form of CO_2, (H_2CO_3), HCO_3' and CO_3'', in proportions determined by pH, water temperature and dissolved salt content. The approximate content of total carbon dioxide is estimated on the basis of pH, temperature and alkalinity.

The alkalinity of inland waters depends on their origin and the kinds of rocks they have encountered (Satomi, 1963), in particular whether they have passed through volcanic rock or limestone areas.

3 SOURCES OF ORGANIC CARBON

Although all organic matter contains carbon, sources which can be supplied as organic fertilizer, and are in a form readily available for living organisms, particularly phytoplankton, are rather limited.

4 SOURCES OF CARBON IN PRODUCTION OF PHYTOPLANKTON

Phytoplankton converts inorganic carbon into organic carbon by photosynthesis, utilizing in most cases CO_2 and HCO_3'. In addition, certain species make use of CO_3''.

The formula for such conversion is as follows:

$$(\Sigma CO_2) = \frac{(A) + (H) - Kw/(H)}{1 + 2\,K_2/(H)} \times (1 + K_2/(H) + (H)/K_1)$$

where ΣCO_2 = total carbon dioxide
A = alkalinity
(H) = concentration of hydrogen ion
Kw = ionization constant of water
K_1 & K_2 = first and second dissociation constants respectively

When total carbon dioxide is exhausted or $\Sigma CO_2 = 0$

$$A = Kw/(H) - (H)$$

Then if water temperature is kept constant, (H) can be determined in theory by alkalinity.

For example, when $\Sigma CO_2 = 0$ at 25°C, one gets the following relationships:

Alkalinity	Theoretical pH-value
m.equiv./ℓ	
0.5	10.7
1.0	11.1
2.0	12.0

One can confirm the above relationships by use of *Scenedesmus* cultured in a glass container. However, in the case of *Chlorella*, one finds that the pH-value does not rise beyond 9.6 - 9.8, with inorganic nitrogen compounds (N) and phosphates (P) still remaining. In other words, there still remain HCO_3' and CO_3'' in the culture medium even when $CO_2 = 0$ (Matsue & Hirano, 1955; Satomi, 1959a).

This seems to indicate that there are certain cases where carbon sources become a limiting factor for the growth of phytoplankton, even though succession of species depends on pH.

It is further observed that phytoplankton absorbs N and P excessively in a culture medium with insufficient supply of carbon sources. This was demonstrated by the author, who successfully induced phytoplankton to grow by addition of CO_2, N, and P to the culture medium deficient in C, N and P respectively (Satomi, 1959b). Post-mortem examination further detected inorganic N and P accumulated in their bodies (Satomi, 1962a).

On the basis of the above evidence, the author concluded that N and P taken in excess have nothing to contribute to the production of phytoplankton. He further found that adequate composition of C-N-P of phytoplankton is approximately 50 : 7 : 1 by weight, which is almost identical with that of marine phytoplankton (Satomi, 1959a). It is pointed out that from the standpoint of fish farming the use of inorganic fertilizer tends to result in a deficiency of C, relative to N and P.

Alkalinity of land waters is generally low in Japan due to the volcanic rocks, its average for rivers being 0.51 milliequiv./ℓ (Kobayashi, 1960). The average for lakes is much the same (Satomi, 1962b). Furthermore, the diffusion of CO_2 from the atmosphere into water is known to be very slow (Verduin, 1956 & 1960; Gessner, 1959).

Judging from the velocity constants for the hydration of CO_2 and the dehydration of H_2CO_3, it is easily seen that the release of CO_2 from the water is much faster than its diffusion into the water (Edsall & Wyman, 1957). In addition, mineralization of phytoplankton further reduces alkalinity (Satomi, 1962a). In fact, the pH-value was observed to rise up to the point where $\Sigma CO_2 = 0$ in a two-ha pond fertilized only by inorganic fertilizers.

Then the question comes to the sources of organic carbon. The author examined the effect of organic acids from plankton bodies, or produced in the process of their decomposition on phytoplankton (Satomi, 1964). It was demonstrated by this study that acetic acid is the only organic acid available for phytoplankton in the presence of CO_2. It is true, as shown by many reports, that a number of organic acids are utilized by phytoplankton, but this needs to be re-examined from the viewpoint of whether they can be fully utilized in the presence of CO_2 in order to prevent alkalinity decreasing and pH value increasing.

The author obtained the following favourable results by application of acetic acid with inorganic fertilizers (N and P).

Number of fish per 3.3m^2	Silver carp	4	1
	Kawachi-buna (crucian carp)	1	4
	Common carp	1	1
Lot with CH_3COOH added	Silver carp	2.23 ton/ha	1.28 ton/ha
	Kawachi-buna	0.40	1.02
	Common carp	0.32	0.33
Lot without CH_3COOH added	Silver carp	1.52	1.04
	Kawachi-buna	0.30	0.72
	Common carp	0.35	0.17

Note(1) Total amount of inorganic fertilizer applied: 4.4 mg-P/ℓ, 25.5 mg-N/ℓ, 60 mg-C/ℓ

(2) Period of experiment: 20 March 1962 - 1 November 1962

5 SOURCES OF CARBON IN PRODUCTION OF ZOOPLANKTON

Since the availability of various carbon sources is important for the production of phytoplankton, which is the primary product of a fertilized fish farm, it is easily seen that it will necessarily affect the production of phytoplankton-feeding zooplankton (e.g. Hazelwood and Parker, 1961; Borecky, 1956).

Fertilization by inorganic fertilizers results in the rise in pH value, adversely affecting the production of Daphnia.

Since there has been no direct evidence to demonstrate the positive relationship between alkalinity and zooplankton, Suginome and Satomi (1966) studied this with a sufficient supply of phytoplankton at constant temperature. From this experiment it was found that high alkalinity exerts a favourable influence on the growth, reproduction and longevity of zooplankton. It was also found that acetic acid, good for the growth of phytoplankton, also accelerates the growth of zooplankton.

High alkalinity also has a favourable effect on aquatic insects, which may be the consequence of a similar action (e.g. Armitage, 1958).

6 EFFECTS ON BACTERIA

As is well known in soil science, bacteria are generally activated at high carbon - nitrogen ratios, to quicken decomposition of organic carbon, which eventually works to reduce this ratio.

The author and Oya (1964) observed the relationship between carbon - nitrogen ratios in the bottom soil and the fish production in a pond fertilized with organic fertilizer (chicken faeces) (Fig 1). It was found that higher alkalinity, if less than 2 milliequiv./ℓ, gives higher fish production. On the basis of these facts, it is assumed that organic matter in bottom soil decomposes faster at higher carbon - nitrogen ratios, eventually to raise the alkalinity and the productivity of water.

Accumulation of cellulose deteriorates the quality of bottom soil (Schäperclaus, 1961) and it is known that decomposition of cellulose depends upon alkalinity and calcium content (Brand, Klust and Mann, 1956). It is thus obvious that fertilization with organic fertilizer should be done with due consideration for the carbon - nitrogen ratio.

7 SOURCES OF CARBON IN FISH PRODUCTION

Since Ohle (1938), there have been many reports published in which the alkalinity is used an an index of fish production. However, the use of this index is based, in most cases, on observation and is not substantiated by experimental evidence.

As is seen from the favourable effects on zoo- and phytoplankton and bacteria, the alkalinity has physiological importance not only for the primary products but also for other organisms at higher levels in the food chains. It is closely connected with the velocity of turnover of materials in fish ponds. Its physiological significance for aquatic insects is not yet known.

A linear relationship between alkalinity and fish production is recognized in the United States (Carlander, 1955), while in Japan a linear relationship is observed between alkalinity and the logarithm of fish production (Satomi, 1962c). This discrepancy is assumed to be due to the difference in the fish utilized; carnivorous fish in the former, and omnivorous and plankton-feeding fish in the latter case.

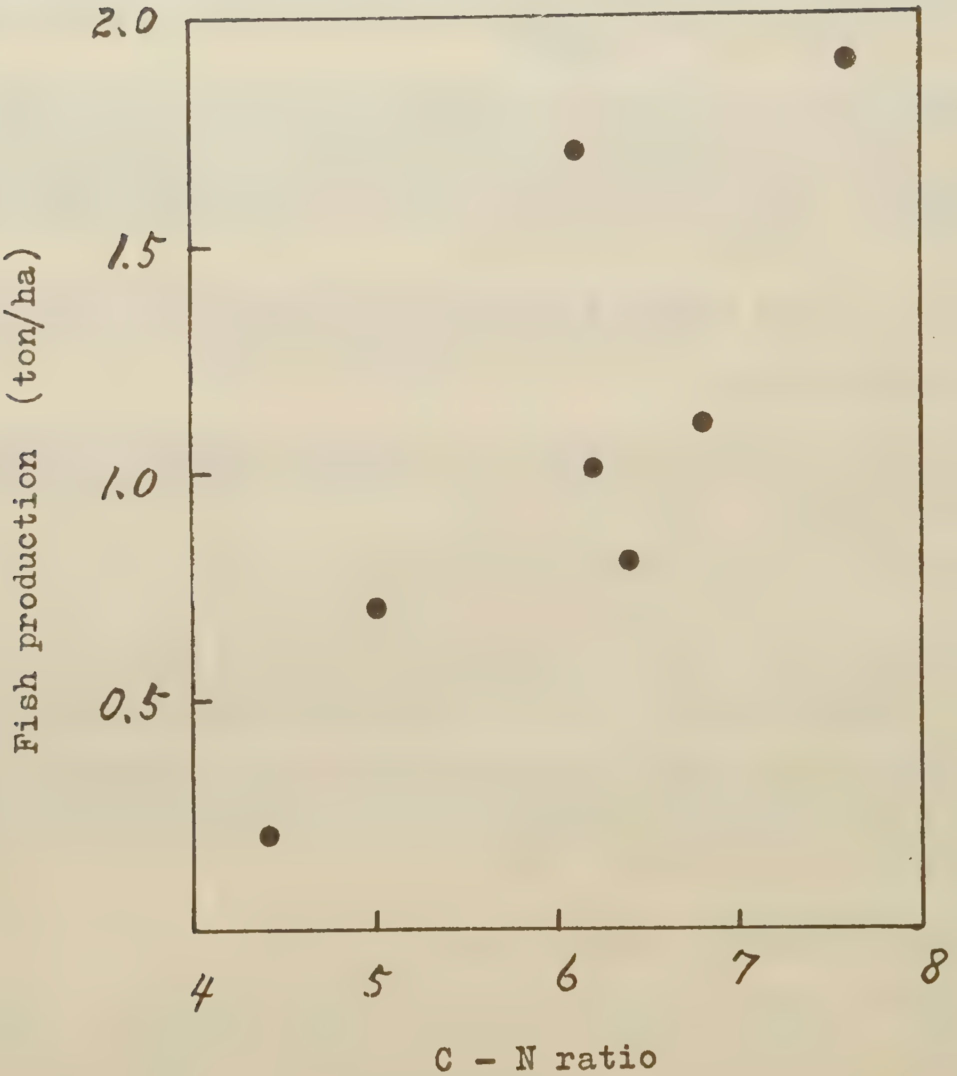

Fig. 1 Production of Kawachi crucian carp at different carbon - nitrogen ratios in the bottom soil in ponds fertilized with organic fertilizer (chicken faeces)

Lastly, it may be pointed out that inorganic carbon is directly assimilated into body-composing organic matter (Sorvacher and Belokopytova, 1960). However, the physiological significance of this phenomenon, and whether there is any organic carbon which is directly assimilated into body-composing organic matter, is not known. The ability of fish to convert inorganic carbon into the organic form (as with inorganic Ca, P and S) should be given due consideration in future in fertilized fish farming, as well as in the study of production biology.

8 REFERENCES

Armitage, K.B., 1958 Ecology of the riffle insects of the Firehole River, Wyoming. Ecology, 39:571-80

Borecky, G.W., 1956 Population density of the limnetic Cladocera of Pymatuning reservoir. Ecology, 37:719-27

Carlander, K.D., 1955 The standing crop of fish in lakes. J.Fish.Res.Bd Can., 12:543-70

Edsall, J.T. and J. Wyman, 1957 Biophysical chemistry. Vol. 1. New York, Academic Press, 699 p.

Gessner, F., 1959 Hydrobotanik. Bd 2. VEB. Deutsch.Vertag der Wissensch., Berlin, 701 p.

Hazelwood, D.H. and R.A. Parker, 1961 Population dynamics of some fresh-water zooplankton. Ecology, 42:266-74

Kobayashi, J., 1960 A chemical study of the average quality and characteristics of river waters of Japan. Ber.Ohara Inst.landw.Biol., 11:313-58

Matsue, Y. and R. Hirano, 1955 On the relation between the carbon dioxide supply and the phytoplankton growth. Jap.J.Limnol., 17:133-40

Ohle, W., 1938 Teichwirtschaftliche Kalkkontrolle und die PH-SBV-Tasche. Z.Fisch., 36: 185-91

Satomi, Y., 1959a Beziehungen zwischen dem geeigneten Stickstoff-Phosphor Verhaeltnis und Alkalinitaet für Phytoplanktonwuchs. Bull.Freshw.Fish.Res.Lab., Tokyo, 8:21-39

____________, 1959b Beiträge zur Kenntnis der Teichdüngungen durch Stickstoff und Phosphordüngermittel bei höherer Planktonsdichte, insbesondere in Bezug auf Kohlensäuregehalt des Wassers. Bull.Freshw.Fish.Res.Lab., Tokyo, 9:1-10

____________, 1962a Untersuchungen über die Remineralisation des Phosphors und Stickstoffs im Phytoplankton, insbesondere in Bezug suf Alkalinität der Medien und andere Milieufaktoren. Bull.Freshw.Fish.Res.Lab., Tokyo, 11:1-9

____________, 1962b Untersuchungen über die Alkalinität des Süsswassers 2. Über den untersuchten Werte und seinen Schwankungen in japanischen hauptsächlichen Seen und Flüssen. Bull.Freshw.Fish.Res.Lab., Tokyo, 12:51-63

____________, 1962c Über die Bedeutung der Alkalinität als Indikator für Binnenfischerei-Produktion. Bull.Freshw.Fish.Res.Lab., Tokyo, 12:65-74

Satomi, Y., Untersuchungen über die Alkalinität des Süsswassers 4. Herausgelöste Menge
1963 beim Kontakt mit den verschiedenen Gesteinen. Bull.Freshw.Fish.Res.Lab., Tokyo, 13:1-6

__________, Über die Verwertung organischer Säuren durch Phytoplankton und dabei
1964 begleitende Veränderung der Alkalinität. Bull.Freshw.Fish.Res.Lab., Tokyo, 13:77-92

Satomi, Y. and S. Oya, April 1964 Annual meeting of the Japanese Society of Scientific
1964 Fisheries

Schäperclaus, W., Lehrbuch der Teichwirtschaft. Berlin, Paul Parey, 582 p.
1961

Sorvachev, K.F. i O.V. Belokopytova, Polgloshenie rybami neogranicheskogo ugleroda iz
1960 okruzhaiushchei sredy i uchastie vobmene veshchestv. Biokhimiia, 25:459-64

Suginome, M. and Y. Satomi, Über den Einwirkungen der pH-Werte und Alkalinität auf Wuchs
1966 und Erzeugungsfähigkeit von Daphnia carinata King, aus Dauereier geschlüpfter Generation. Bull.Freshw.Fish.Res.Lab., Tokyo, 15:113-22

Verduin, J., Energy fixation and utilization by natural communities in western Lake Erie.
1956 Ecology, 37:40-50

__________, Phytoplankton communities of western Lake Erie and the CO_2 and O_2 changes
1960 associated with them. Limnol.Oceanogr., 5:372-80

Vel'tishcheva, I.F., Proniknovenie ugleroda (C^{14}) karbonata iz vody i raspredelenie ego
1961 v tele ryby. Trudy vsesoiuz.nauch.-issled.Inst.morsk.ryb.Khoz., 44:23-6

von Brandt, A., G. Klust and H. Mann, Der Zelluloseabbau in Fischteichen. Arch.Fisch.
1956 Wiss., 7(1):31-40

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THERMAL CHARACTERISTICS OF CARP PONDS

by

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Abstract

Observations on temperature variations were carried out in spawning, nursery and rearing ponds at the Solysz Experimental Farm of the Laboratory of Water Biology, Polish Academy of Sciences. The results indicate that in all ponds distinct differences exist in time-space temperature distribution. These differences depend on the size of the pond, depth being the decisive factor. Diurnal amplitude and the vertical gradient of water temperature change in inverse proportion to depth. Horizontal gradients are mostly caused by depth variations in different parts of ponds. The extent of pond surface influences thermodynamics only when wind velocity is high. Nursery ponds have more favourable thermal conditions than spawning ponds. Vertical thermal sections of all investigated ponds indicate that convections include the whole stratum of water. Increasing wind velocity leads to the formation of turbulent movements. Its influence increases with decrease in relative depth of ponds.

II/E-15

CARACTERISTIQUES THERMIQUES DES ETANGS DE CARPICULTURE

Résumé

Des observations sur les variations de température de l'eau ont été effectuées dans des étangs de reproduction, d'alevinage et de production de la ferme expérimentale Solysz dépendant du Laboratoire de biologie hydrologique de l'Académie des Sciences de Pologne. Les résultats indiquent que dans tous les étangs il existe des différences marquées de répartition des températures dans le temps ou dans l'espace. Ces écarts dépendent de la dimension de l'étang et notamment de sa profondeur. L'amplitude diurne et le gradient vertical de la température de l'eau varient en proportion inverse de la profondeur. Les gradients horizontaux sont généralement dus à des variations de profondeur dans les différentes parties de l'étang. La superficie de l'étang ne joue un rôle thermodynamique que lorsque la vitesse du vent est élevée. Dans les bassins d'alevinage les conditions thermiques sont plus favorables que dans les bassins de reproduction. La section thermique verticale de tous les étangs étudiés indique que des phénomènes de convection intéressent l'ensemble du plan d'eau. Lorsque la vitesse du vent s'accroît, il entraîne la formation de turbulences. Son influence est d'autant plus forte que le bassin est moins profond.

CARACTERISTICAS TERMICAS DE LAS CARPAS DE ESTANQUE

Extracto

Han sido llevadas a cabo observaciones sobre las variaciones de la temperatura en estanques de desove, de cría y de desarrollo en la Granja Experimental de Solysz del Laboratorio de Biología Acuática de la Academia Polaca de Ciencias. Los resultados indican que en todos los estanques existen señaladas diferencias en la distribución de la temperatura en el tiempo y el espacio. Estas diferencias dependen del tamaño del estanque, siendo la profundidad el factor decisivo. La amplitud diurna y el gradiente vertical de la temperatura del agua varían en proporción inversa a la profundidad. Las gradientes horizontales son determinados en su mayor parte por las variaciones de profundidad en las distintas partes de los estanques. La extensión de la superficie del estanque influye en la termodinámica solamente cuando la velocidad del viento es elevada. Los estanques de cría tienen condiciones termales más favorables que los de fecundación. Las secciones verticales termales de todos los estanques investigados indican que las convecciones abarcan todos los estractos del agua. El aumento de la velocidad del viento determina la formación de movimientos turbulentos. Su influencia aumenta al disminuir la profundidad relativa de los estanques.

1 INTRODUCTION

In carp rearing, ponds of different sizes and depths are used according to the changing environmental requirements of fish at different stages of their life. The thermo-dynamics of these ponds show significant differences, which result from differences in the heat capacity of individual ponds related to the volume of water. Other factors such as the relation of depth to area, development of the bank line, and relation of the height of dyke to the surface of the water are also of importance (Geiger, 1942; Tuszko, 1952; Starmach, 1956). Certain differences in the thermal balance of different types of pond result from differences in the transfer of heat turbulence between air and water. This transfer is directly proportional to the vertical gradient of air temperature over the water, which is also a function of the size of the pond (Szumiec, 1962).

This paper describes the thermo-dynamics of different ponds used for the rearing of carp and discusses the thermal differences and the relationships between time-space alterations of temperature and the size of the pond.

2 DESCRIPTION OF THE PONDS

Observations were carried out in carp ponds at the Golysz Experimental Farm of the Laboratory of Water Biology of the Polish Academy of Sciences (49° 51′North, 18° 46′West).

Measurements were made in spawning ponds with a surface area of 0.023 ha and a mean depth of 30 cm, three types of nursery ponds (nursery ponds I with a surface area of 0.47 ha and a mean depth of 40-50 cm, nursery ponds II with a surface area of 1.2 ha and a mean depth of 60 cm, nursery ponds III with a surface area of 1.7 ha and a mean depth of 80 cm), and ponds stocked with one- and two-year old carp (commercial fish) with a surface area of three to four ha and a mean depth of 100 cm.

The spawning ponds were used for 10 to 14 days, usually in the second half of May or first half of June, the dates depending on the meteorological conditions. Nursery ponds I are used in June or sometimes in the early part of July, nursery ponds II from the beginning or the second part of July to 15 August, nursery ponds III until the spring of the next year. Rearing ponds are used during the whole growing season, from the middle of April to the middle or the end of October. The present studies covered the period of flooding of spawning ponds, from the middle of May till the end of the growing season at the end of October.

Spawning and nursery ponds observed in this study belonged to a complex specially organised for research and production. The rearing ponds were on a neighbouring farm at a distance of 500 m from the first one. At both places the surroundings were similar and the ponds were not overgrown nor shaded by trees or buildings.

3 RESULTS

In conditions of sunny and windless weather all ponds stratified during the day, but with variations in the vertical temperature gradients (Fig. 1). At noon the mean difference between surface and bottom temperatures in shallow spawning ponds amounted to 2.9°C, and in rearing ponds to 1.5°C (Table I).

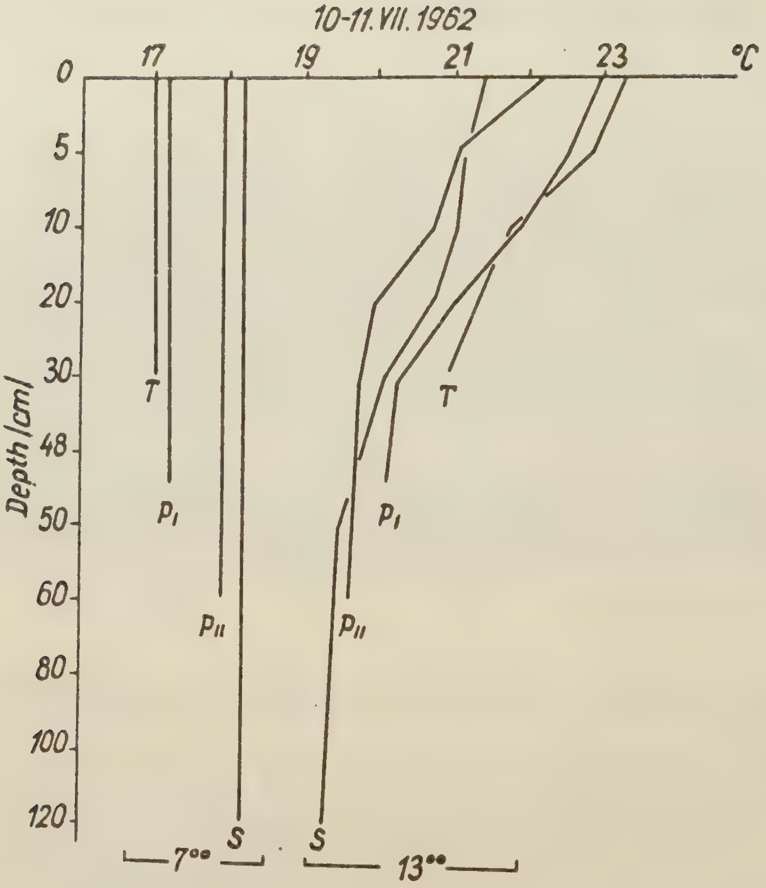

Fig. 1 Vertical thermal stratification of water in conditions of sunny weather in a spawning pond (T), in nursery pond I (PI), in nursery pond II (PII), and in a rearing pond (S), (simultaneous measurements)

Table I

Differences of temperature (°C) between surface and bottom strata, sunny weather, in various types of ponds (mean noon values for a number of years)

Spawning	Nursery I	Nursery II	Nursery III	Rearing
2.9	2.3	1.6	1.3	1.5

Assuming that one m is the unit of depth, it was calculated that the vertical temperature gradient was seven times as great in the spawning as in the rearing ponds (Table II), and that the vertical gradient diminishes in proportion to the distance from the pond surface (i.e. the temperature gradient decreases with increasing depth, being greatest near the surface of the pond).

Table II

Vertical gradients of water temperature ($^{o}C/1m$), sunny weather, in various types of ponds (mean noon values for a number of years)

Spawning	Nursery I	Nursery II	Nursery III	Rearing
9.7	5.8	2.7	1.6	1.3

The gradient calculated per meter depth and based on the entire water column is greatest in spawning ponds, reaching more than $12^{o}C/m$. (It is the equivalent of more than $30^{o}C/m$ in the bottom strata where the fall in gradient is steepest in these ponds). The gradient is less steep in nursery ponds and ponds with flowing water than in spawning ponds (Fig. 1 and Table II), but in ponds with no current it also reaches the equivalent of $30^{o}C/m$ in certain strata. Spawning ponds and larger ponds also differ in that there is no thermocline in spawning ponds. This begins to appear in nursery pond I; it occurs in these ponds at a depth of 5-10 cm, in nursery ponds II and III at a depth of 5-20 cm, and in rearing ponds at a depth of 20-40 cm. Isothermy, or possibly poikilothermy with a minimum gradient, is generally observed in all ponds, the latter being mostly observed in deeper ones.

An increase in wind velocity above a certain minimum value equalises the temperature differences between surface and bottom even during favourable insolation. The wind velocity causing isothermy varies for different types of pond, and depends on the temperature difference between surface and bottom waters (the calculated "relative depths", after Starmach, 1958, given in Table III). In spawning ponds where this is greatest, a wind velocity greater than 6m/sec still does not cause isothermy, and the steepest gradient continues to be observed near the bottom (Fig. 2). In rearing ponds a wind velocity of about 3m/sec causes isothermy. Sellmayer (1934) mentions a similar influence of wind in a large pond.

Table III

Wind velocities causing isothermy in ponds of different relative depths

	Spawning	Nursery I	Nursery II	Nursery III	Rearing
Relative depth $1 \times 10^{5}/m$	130	11	6	5	5
Wind velocity m/sec	$>$ 6	5	4	4	3

Temperature profiles of these ponds with wind velocities of 4-6 m/sec are shown in Fig. 2, based on simultaneous measurements made during the noon hours. Only the rearing ponds were isothermal the whole time. Besides the differences in relative depth between

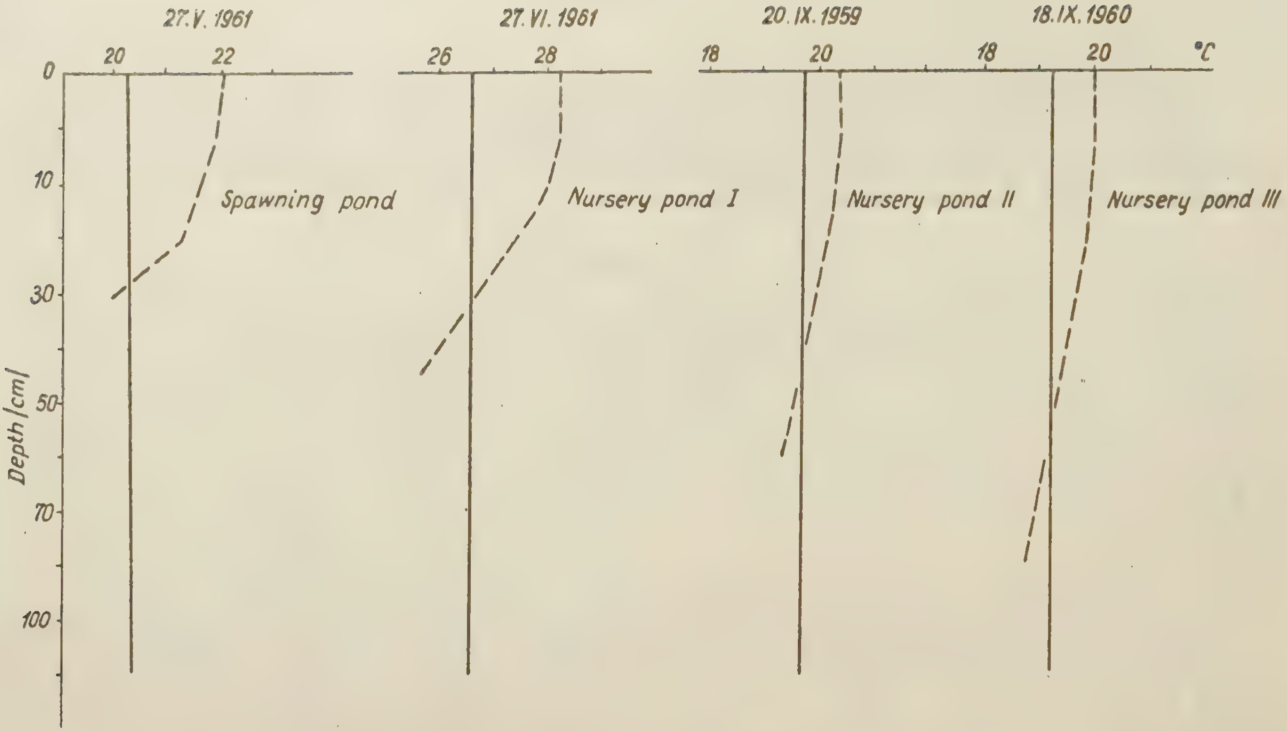

Fig. 2 Vertical thermal stratification in spawning and nursery ponds (– –) and rearing ponds (———), in sunny and windy weather, (simultaneous measurements)

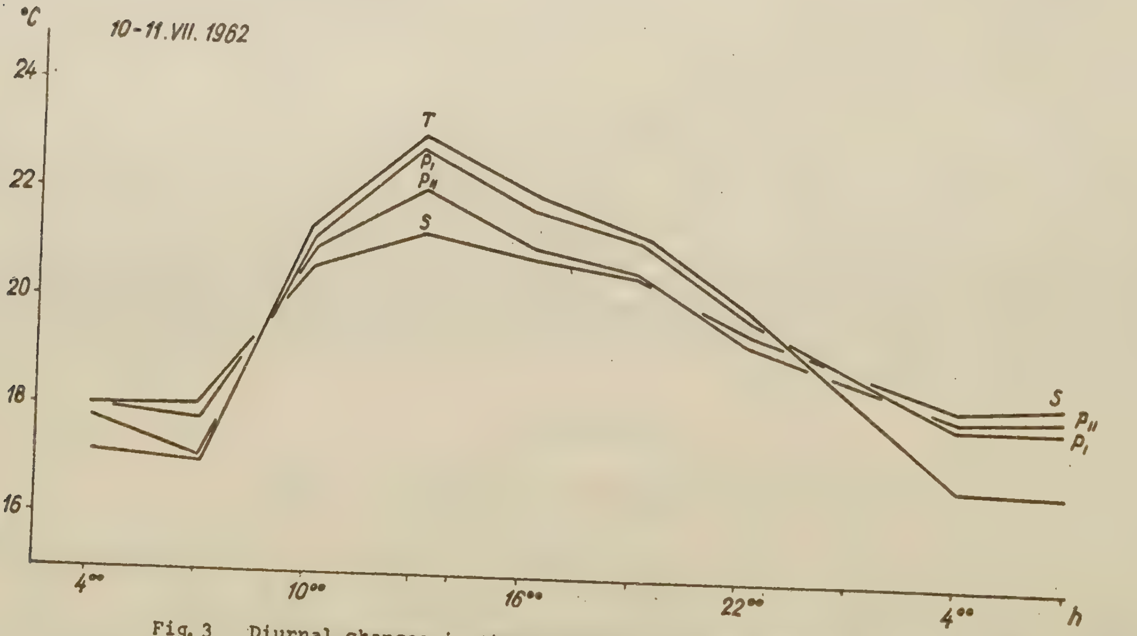

Fig. 3 Diurnal changes in the temperature of the surface stratum of water in a spawning pond (T), nursery pond I (PI), nursery pond II (PII) and in a rearing pond (S), in conditions of sunny weather (simultaneous measurements)

the types of pond, the resistance caused by the water at high temperature (Kühlman, 1961) in the spawning ponds during sunny weather also counteracts mixing.

Temperature changes per unit time in sunny weather are greatest in spawning ponds, least in rearing ponds (Table IV); this is mostly due to differences in depth between the ponds.

Table IV

Maximum differences of temperature (°C) in the surface layers observed in shallow and deep ponds, sunny weather, (mean noon figures for a number of years)

Spawning	Nursery I	Nursery II	Nursery III	Rearing
1.2	2.2	2.8	4.0	5.0

The diurnal temperature variations in all the ponds investigated follow the same sinusoidal curve (Fig. 3), differing only in amplitude. This is greatest in spawning ponds and decreases with depth of pond (Table V).

Table V

Diurnal amplitude of temperature (°C) in the surface layers of various types of ponds (mean figures for a number of years)

	Spawning	Nursery I	Nursery II	Nursery III	Rearing
Sunny days	6.8	5.9	3.6	2.9	2.8
All days	4.6	3.9	2.1	1.9	1.9

In the investigated ponds the amplitude of diurnal temperature variation (A) x depth of reservoir (Z) is constant and the constant in the formula (AZ = constant) amounts to about 200.

Besides variations in diurnal amplitude there are also differences in the speed of temperature changes in individual ponds (Table VI), changes occurring most rapidly in spawning ponds (up to 30°/h) and least rapidly in rearing ponds (not exceeding 1°C/h). Temperature extremes appear somewhat later in larger ponds than spawning ponds, but not exceeding three hours later.

Table VI

Changes of temperature per time unit (°C/1h) in morning hours, sunny weather, in various types of ponds (mean figures for a number of years)

Spawning	Nursery I	Nursery II	Nursery III	Rearing
0.8	0.6	0.4	0.3	0.3

The influence of meteorological factors (such as overcast skies) is exerted most rapidly and distinctly on the thermo-dynamics of the spawning ponds. As the size of the pond and therefore its thermal capacity increases, this influence is proportionately greater and is observed only after a longer lapse of time.

4 CONCLUSIONS

These observations show that in the ponds used for carp rearing the time-space temperature distributions vary according to the size of pond, depth being the decisive factor. In the ponds investigated diurnal amplitude and vertical temperature gradient both change in inverse proportion to their depth. Depth differences also cause stratification. The surface area of the pond only influences the thermo-dynamics when the wind velocity is high, isothermy being observed in large ponds at velocities which are not sufficient for equalising temperatures in nursery or spawning ponds.

The temperature ranges indicate that nursery ponds have more favourable thermal conditions than the spawning ponds. In nursery ponds the temperature does not fall appreciably at dawn, as in spawning ponds, and the water warms up more gradually during the morning.

The thermal characteristics described here permit conclusions on the dynamics of carp ponds. On a windless sunny day, at about 0600 or 0700 hours, the surface layers of water begin to warm up and their density diminishes until the hour of maximum temperature. The water strata near the bottom are then cooler and heavier and so a stable equilibrium is established; convection currents are not observed. After exceeding the maximum temperature (after 1400 or 1500 hours) the direction of the warm current alters, the surface strata cool down and, being heavier, move to the bottom. This state of unstable equilibrium and the convection movements connected with it last throughout the night, up to the moment when the water temperature exceeds its minimum value. Vertical thermal sections of all investigated ponds indicate that convection movements affect the whole water column, as in all ponds isothermy is usually observed during the night.

The influence of wind being greater in them, larger movements are observed in rearing ponds. Turbulent mixing is also facilitated by smaller differences of density between the surface and bottom layers of the water in the ponds. In spawning ponds, as indicated by temperature measurements, mixing does not take place even with a considerable wind velocity. A similar influence of wind on the thermodynamics of shallow ponds has already been observed by Gieysztor (1934).

5 REFERENCES

Geiger, R., 1942 Das Klima der bodennahen Luftschicht. Braunschweig.

Gieysztor, M., 1934 Limnologische Untersuchungen an einigen Kleingewässern. Arch.Hydrobiol.Ryb., 8:75-148

Kühlmann, D.H.H., 1961 Thermodynamische Untersuchungen in Kleingewässern verschiedener landschaftlicher Exposition. Verh.Int.Ver.Limnol., 15:87-94

Sedlmayer, K.A., 1934 Ein Beitrag zur Klimatologie des Teiches. Z.Fisch., 29:805-15

Starmach, K., 1956 Staw jako środowisko hodowlane. Hodowla ryb stawowych. Warszawa, PWRiL

Starmach, K., 1958 Hydrobiologiczno podstawy uzytkowania przez wodociagi wód plytkich zbiorników rzecznych. Polsk.Arch.Hydrobiol., 4(17):9-66

Szumiec, M., 1962 Czasowo-przestrzenny rozklad temperatury nad woda i gleba w najnizszych warstwach powietrza. Przegl.geofiz., 7(15):3, 157-68

Tuszko, A., 1952 Budowa stawów rybnych. Warszawa, PWRiL

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II/E-16

EXPERIMENTS IN THE FERTILIZATION OF MINNESOTA FISH REARING PONDS

by

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Abstract

Walleye pike (Stizostedion vitreum) ponds in Minnesota are fertilized each winter with organic fertilizers. In spring they are filled with water and stocked with walleye fry from nearby hatcheries. Fingerlings are harvested in July and August. Present fertilization methods are often inadequate and, consequently, the supply of plankters and insects for consumption by the fingerlings is not adequate, and fish must be harvested at a smaller size than is desirable to prevent large losses of fish from cannibalism.

In 1957, ten one-acre drainable ponds were built at Waterville, Minnesota for a study of fertilization methods that could be used in Minnesota waters. Both organic and inorganic fertilizers have been tested separately and in various combinations. Pond conditions were studied in detail at weekly intervals.

The studies have shown that most fertilizers produce extremely large populations of zooplankters in May and June,when the demand for food by the small fish is very low, while in July and August when the fish demand large quantities of food, zooplankton populations are very small. Most of these fertilizers have no measurable effect on the production of bottom fauna in a season of the year when the fish need these food organisms.

Most fertilizers contain phosphorus that is readily liberated into the pond waters; this produces dense mats of filamentous algae or thick growths submerged aquatic vegetation.

The best fertilization practice tried in the first six years of the project was a combination of dried sheep manure applied in one dose in April and weekly applications of a yeasty poultry food from mid-June to mid-August. The production of zooplankters and bottom fauna was better throughout the season than with any other fertilization practice studied.

EXPERIENCES DE FERTILISATION DANS LES ETANGS DE PISCICULTURE AU MINNESOTA

Résumé

Au Minnesota, les étangs d'élevage de walleye pike (Stizostedion vitreum) sont fumés chaque hiver avec des engrais organiques. Au printemps, ils sont mis en eau et empoissonnés avec des alevins de walleye provenant de centres d'alevinage voisins. Les fingerlings sont recueillis en juillet et en août. Les méthodes actuelles de fertilisation sont souvent insuffisantes, de sorte que, les planctontes et insectes que consomment les fingerlings n'étant pas assez abondants, il devient nécessaire pour éviter des pertes considérables due au cannibalisme de récolter les poissons d'une taille inférieure à celle souhaitable.

En 1957, on a construit à Waterville, Minnesota, dix étangs drainables d'un acre, afin d'étudier les méthodes de fumure les plus appropriées. Des engrais organiques et inorganiques ont été essayés, séparément et mélangés dans des proportions variables. Les conditions dans les étangs étaient observées minutieusement chaque semaine.

Ces études ont montré que la plupart des engrais favorisent une forte production de zooplancton en mai et en juin - époque où les besoins alimentaires des alevins sont très faibles - tandis qu'en juillet et en août, lorsque les poissons ont besoin de beaucoup de nourriture, le zooplancton est très peu abondant. Ces engrais n'ont en général aucun effet sensible sur la production de benthos à une époque de l'année où les poissons ont besoin ie ces organismes pour s'alimenter.

La plupart des engrais contiennent du phosphore qui est facilement libéré dans les eaux de l'étang et favorise la croissance de bancs épais d'algues filamenteuses ou le développement d'une végétation aquatique submergée très dense.

Au cours des six premières années d'expériences, on a constaté que les meilleurs résultats étaient obtenus en associant le fumier séché de mouton, appliqué en une seule dose en avril, à des aliments pour volaille à base de levure, appliqués à dose hebdomadaire de la mi-juin à la mi-août. Avec ce traitement on a constaté pendant toute la saison une production de zooplancton et de benthos supérieure à celle obtenue avec toutes les autre méthodes de fumure essayées.

EXPERIMENTOS EN LA FERTILIZACION DE PECES EN LOS ESTANQUES PISCICOLAS DE MINNESOTA

Extracto

Los estanques de lucio amarillo (Stizostedion vitreum) se abonan todos los inviernos con fertilizantes orgánicos. En la primavera se llenan de agua, poblándose con jaramugos de dicha especie de los criaderos vecinos. Los métodos actuales de fertilización son en muchos casos inadecuados y, por consiguiente, el suministro de organismos planctónicos y de insectos para su consumo por los pececillos pequeños no es suficiente, y los peces deben recogerse con un tamaño menor del deseable para evitar grandes pérdidas debidas al canibalismo.

En 1957, se construyeron en Waterville, Minnesota, diez estanques de un acre con drenaje para estudiar los métodos de fertilización que se podrían seguir en las aguas de Minnesota. Tanto los fertilizantes orgánicos como los inorgánicos se han ensayado por separado y en diversas combinaciones. Se estudiaron detalladamente a intervalos semanales las condiciones de los estanques.

Los estudios han demostrado que casi todos los fertilizantes producen poblaciones muy abundantes de zooplancton en mayo y junio, época en que los peces pequeños necesitan poco alimento, mientras que en julio y agosto, cuando los peces necesitan grandes cantidades de alimento, las poblaciones de zooplancton son muy pequeñas. Casi todos

estos fertilizantes no ejercen consecuencias apreciables en la producción de fauna del fondo en una época del ano en que los peces necesitan estos organismos alimentarios.

La mayoría de los fertilizantes contienen fósforo que se libera con rapidez en las aguas de los estanques; éste constituye densas formaciones de algas filamentosas o formaciones espesas de vegetación acuática sumergida.

El mejor procedimiento de fertilización que se probó en los seis primeros años del proyecto fué una combinación de estiércol de oveja seco, aplicado en una dosis en abril, y aplicaciones semanales de un alimento ligero para aves de corral desde mediados de junio a mediados de agosto. La producción de organismos zooplanctónicos y de fauna de fondo fué mejor durante la temporada que con cualquier otro procedimiento de fertilización estudiado.

1 INTRODUCTION

The Minnesota Fisheries Organization raises from five to twelve million fingerlings of the walleye (Stizostedion v. vitreum) for stocking of lakes. Most of these fish are produced in drainable ponds that have been built on suitable sites throughout the lake regions. The remainder are raised in natural ponds that usually cannot be filled or drained and in which water levels are regulated by rainfall, spring seepage or water table levels. The Organization operates 36 drainable ponds with a combined area of 263 ha. The number of natural ponds in use in any one year is determined by water levels and the resulting suitability of the ponds for fish production.

The size of the fish populations raised in these ponds usually varies somewhat from year to year because of losses from insect predation, cannibalism, or summer kill due to low oxygen levels. Even when the pond manager is able to control these factors or minimize their effects, yields still vary from year to year because of harvesting practices. If the ponds are harvested in mid-summer when the fish are small, the number of fish removed is larger than in years when the ponds are harvested in late summer or early fall when the fish are larger. This relationship between size of fish at harvest time and total yield (Fig. 1) holds until the basic fertility of the pond changes.

Chemical analyses of soil and water from both natural and artificial ponds have shown that the quantity of fish produced in a pond is more dependent upon the organic content of the soil than on the nitrogen content of the water. This relationship exists even though the primary food of fingerling walleyes during the first part of summer is microcrustaceans that depend indirectly upon water-borne nutrients for their existence. In all Minnesota ponds studied, zooplankton populations have been cyclic, with the greatest plankton pulse in the spring. During mid-summer microcrustaceans become scarce and walleye fingerlings either change to insect foods or become cannibalistic. In ponds where the organic content of the soil is greater than 4.0 percent, there are usually enough aquatic insects (especially Tendipedid larvae) to feed the fingerlings until microcrustaceans become abundant again in late summer. In ponds with less than 4.0 percent organic matter in the soil, insects are usually scarce and fingerlings are often lost from cannibalism (Fig. 2) when there is a shortage of microcrustaceans. Soils of a given organic content usually produce more fish in natural ponds (represented by bars with vertical stripes in Fig. 2) than in drainable ponds (white bars) where the water is changed every year.

Fertilization practices for the drainable walleye ponds are designed mostly to supply organic materials (usually barnyard manure is used) to grow bacteria which in turn feed microcrustaceans. In fertilized ponds cladocera populations in May and June are more than adequate to feed all the fry and small fingerlings. However, copepod and bottom fauna populations do not benefit greatly from these practices, and most ponds fertilized in this manner have an insufficient supply of fish food organisms to feed the larger fingerlings of July and August. Most organic fertilizers release enough phosphorus into the water to promote growths of algae or aquatic vegetation.

Fish culturists have obviated the problem of food shortages in July and August by removing the fish before they become cannibalistic. Consequently, pond reared walleyes may be stocked in lakes at such a small size that they cannot compete with native fish and are probably eaten by both perch and walleyes native to the lake.

In 1957 the United States Department of Interior under the Dingell-Johnson program provided funds for the construction and operation of ten 0.4 ha ponds at Waterville, Minnesota for a study of various fertilization methods and their effect on the production of fish food organisms. The plan of operation for the twelve-year study was designed to provide information on types and amounts of organisms produced by various fertilizers, fluctuations in biotic populations throughout the growing season and from year to year, effect of each fertilizer on soil and water fertility, and nuisance conditions that might result from various fertilization methods.

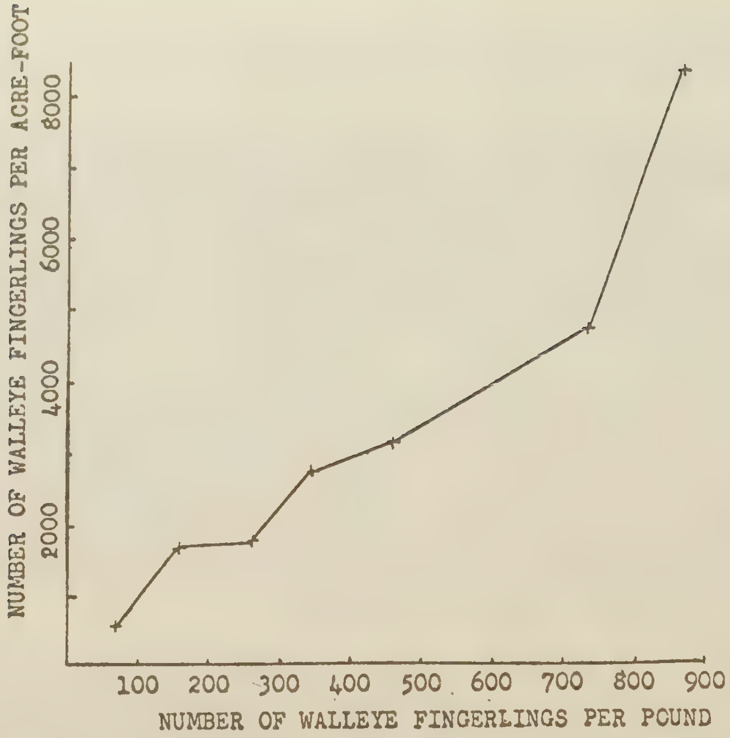

Fig. 1 Relationship between population size and size of fish at harvest in Minnesota drainable walleye rearing ponds.

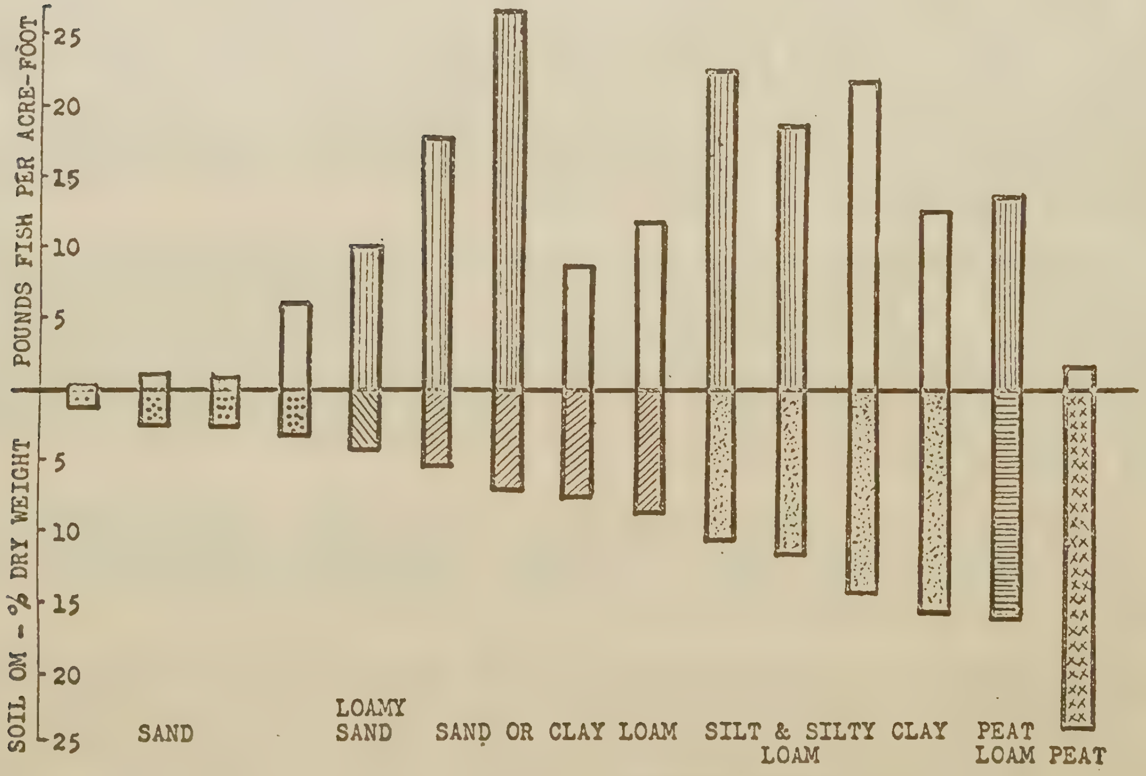

Fig. 2 Relationship between organic content of the soil and fish production in Minnesota artificial and natural walleye rearing ponds. Bars with vertical strips represent natural ponds. White bars represent artificial ponds.

It should be noted that these ponds have quite hard water (total alkalinity 114 ppm) and a moderate basic nitrogen and phosphorus fertility (see Fig. 3). In the following discussion concentrations of nitrogenous compounds are recorded as nitrogen and all phosphorus analyses are for total phosphorus as obtained from acid digestion of water samples. Concentrations are recorded as pounds per acre foot. These can be transformed to parts per million by dividing by 2.718 and to kilograms per hectare by multiplying by 1.1204.

2 POND FERTILIZATION

The large walleye rearing ponds in Minnesota - often as large as 16 ha - are fertilized with organic manures in late fall or early winter when the bottoms are frozen hard enough to support heavy trucks or tractors. In March each pond is filled with water from the nearest lake or river. Each pond is treated with fuel oil to kill predatory insects and is stocked with fry in May. Fingerlings are harvested in July or August, and the ponds are left drained over winter. The experimental ponds at Waterville are operated under a similar plan but are not stocked with fish.

The objectives in fertilizing Minnesota rearing ponds are to increase microcrustacean populations in July and August and bottom fauna populations in July while at the same time keeping growth of algae and aquatic vegetation at minimum levels.

Inorganic fertilizers that have been recommended by some pond workers in the United States usually contain large amounts of nitrogenous compounds and enough phosphorus to produce vegetation problems in Minnesota where ponds often have a high natural fertility. Most organic fertilizers contain less nitrogen and phosphorus and the rate of release into the pond waters is slower. For example, commonly used inorganic fertilizers with 2.2 kg of nitrogen per 1,000 m^3 of water will also supply 1.3 to 1.9 kg of phosphorus. In contrast organic fertilizers that will provide 2.2 kg of nitrogen will supply only 0.6 to 0.8 kg of phosphorus. Even this small amount of phosphorus is apt to result in vegetation problems in Minnesota ponds.

During the first year of this study all ponds were filled with water in June and none were fertilized. After one season of study, those most similar in water and soil chemistry and production of aquatic animals were paired for future experiments. Two ponds were operated as unfertilized controls. Another pair fertilized with enough dried sheep manure to provide 2.2 kg of nitrogen per 1,000 m^3 of water (the fertilization rate in the large production ponds) were considered to be fertilized controls. The remaining three pairs were fertilized during 18 pond seasons with ammonium nitrate, superphosphate, muriate of potash, a chelate, dried sheep manure, and brewer's yeast.

In the unfertilized control ponds the nitrogen content of the water was highest in April and May with a gradual decline until the ponds were drained in August (Fig. 3). Phosphorus was highest in April and uniformly low the remainder of the season. Zooplankton populations were moderately high in all seasons but not adequate for fish production in July and August. Bottom fauna populations were low most of the summer.

2.1 Inorganic fertilizers and chelat

Two ponds were fertilized with enough ammonium nitrate to provide 2.2 kg of nitrogen per 1,000 m^3 of water. The ammonia and the nitrate in this fertilizer were in solution within a few hours, but in two months denitrification processes had apparently released most of the added nitrogen into the atmosphere as nitrogen gas (Fig. 4) (the heavy lines in this and succeeding figures represent total nitrogen of the control pond). Microcrustacean and bottom fauna populations were not increased over those in the control pond by this fertilization.

Two ponds were fertilized with enough superphosphate to supply 1.7 kg of P_2O_5 per 1,000 m^3 of water. This fertilizer made no contribution to the organic content of the pond water (Fig. 6). The amount of phosphorus so added was enough to produce dense mats of

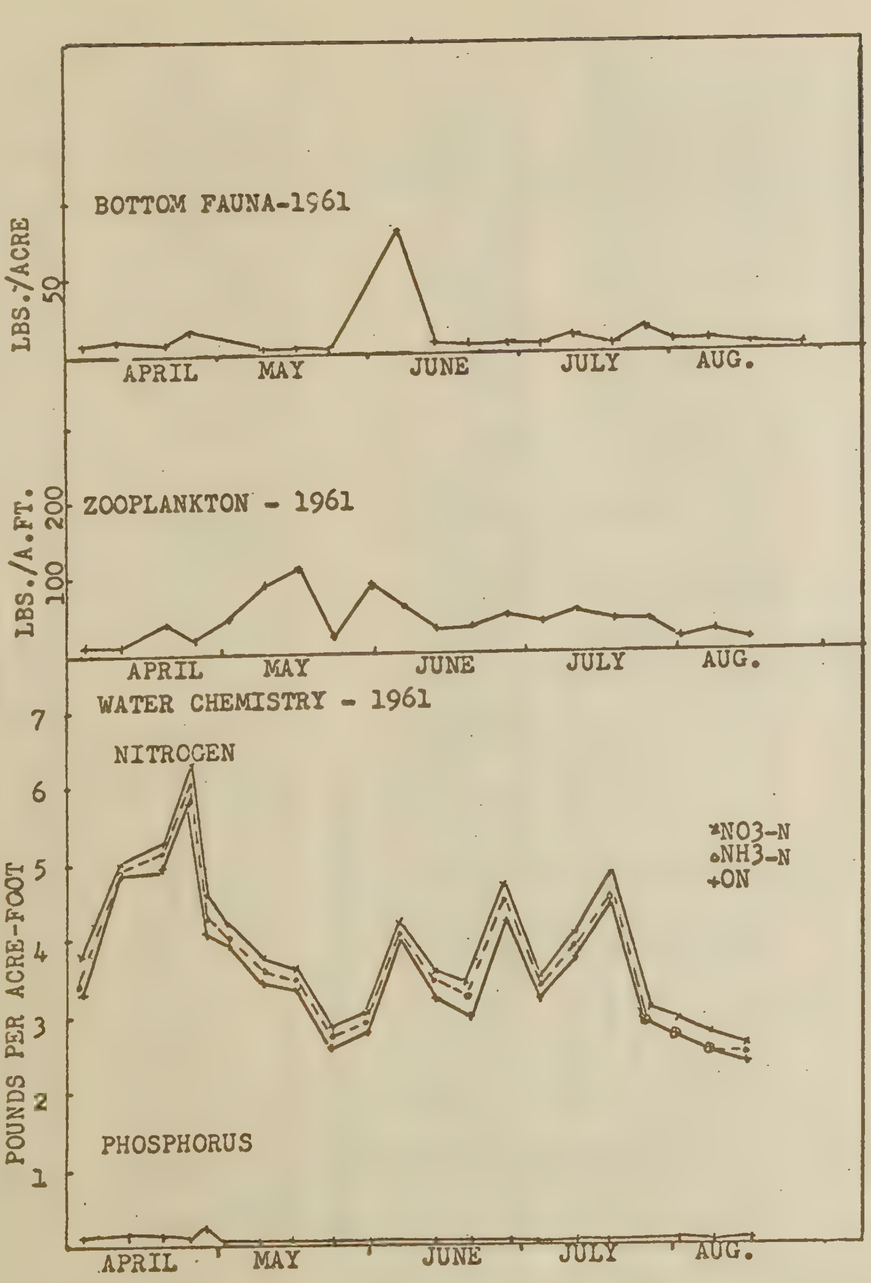

Fig. 3 Water chemistry, zooplankton and bottom fauna populations of Waterville experimental pond 3 which was used as a control from 1958 to 1963.

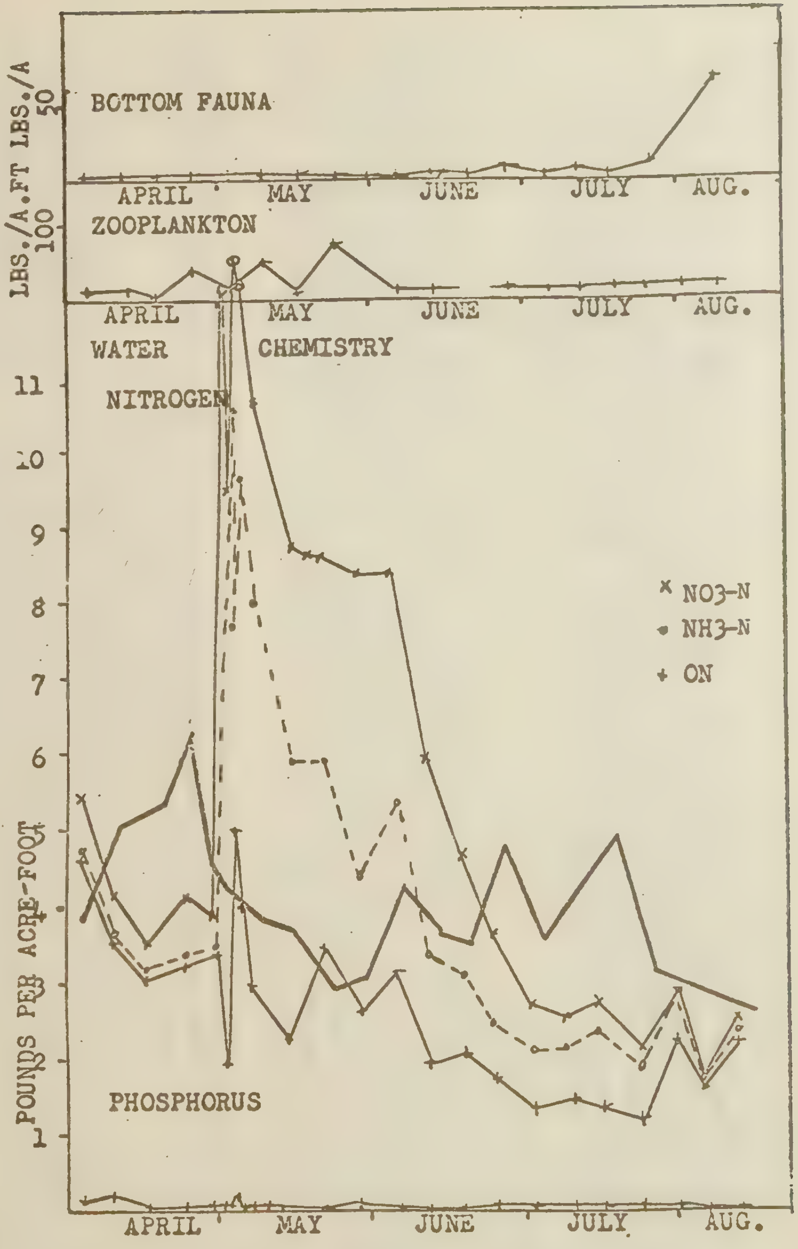

Fig. 4 Water chemistry, zooplankton, and bottom fauna populations of Waterville experimental pond 2 which was fertilized with enough ammonium nitrate to supply 6.0 pounds of nitrogen per acre-foot of water in 1960.

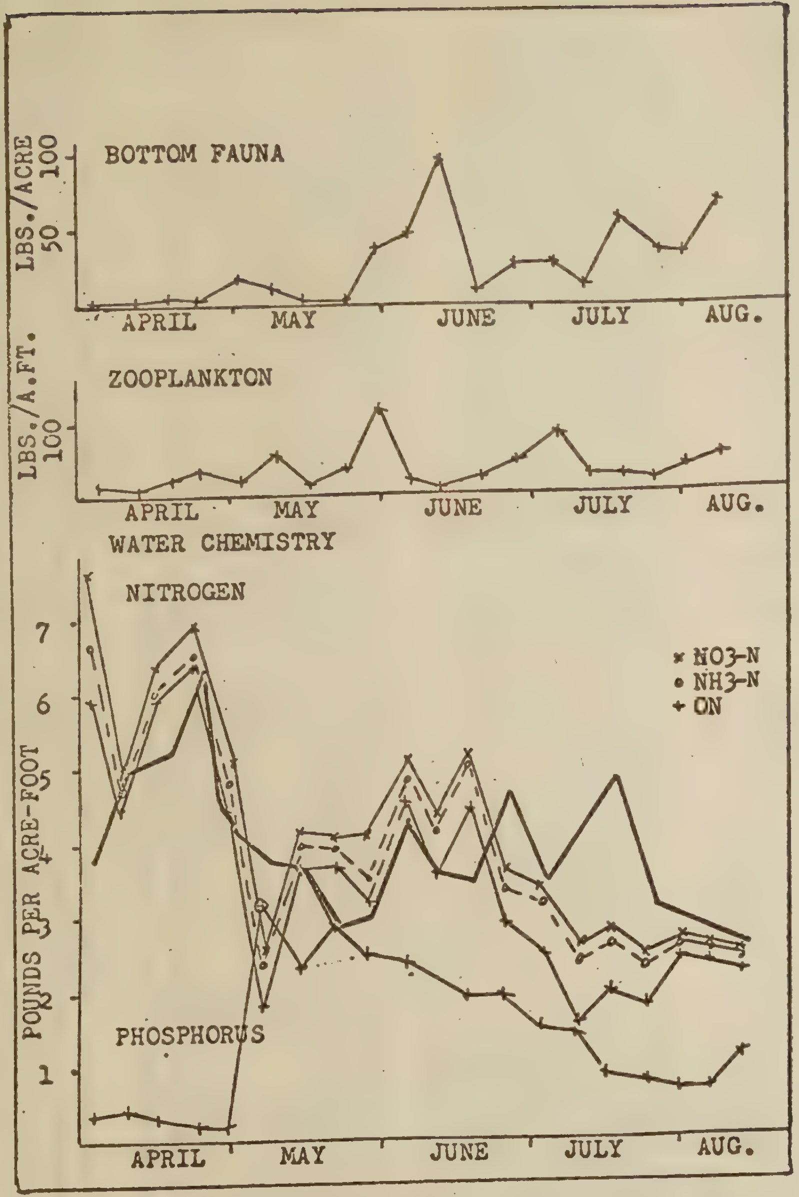

Fig. 5 Water chemistry, zooplankton and bottom fauna populations of Waterville experimental pond 1 which was fertilized with enough superphosphate to supply 6.0 pounds of P_2O_5 per acre-foot of water in 1960.

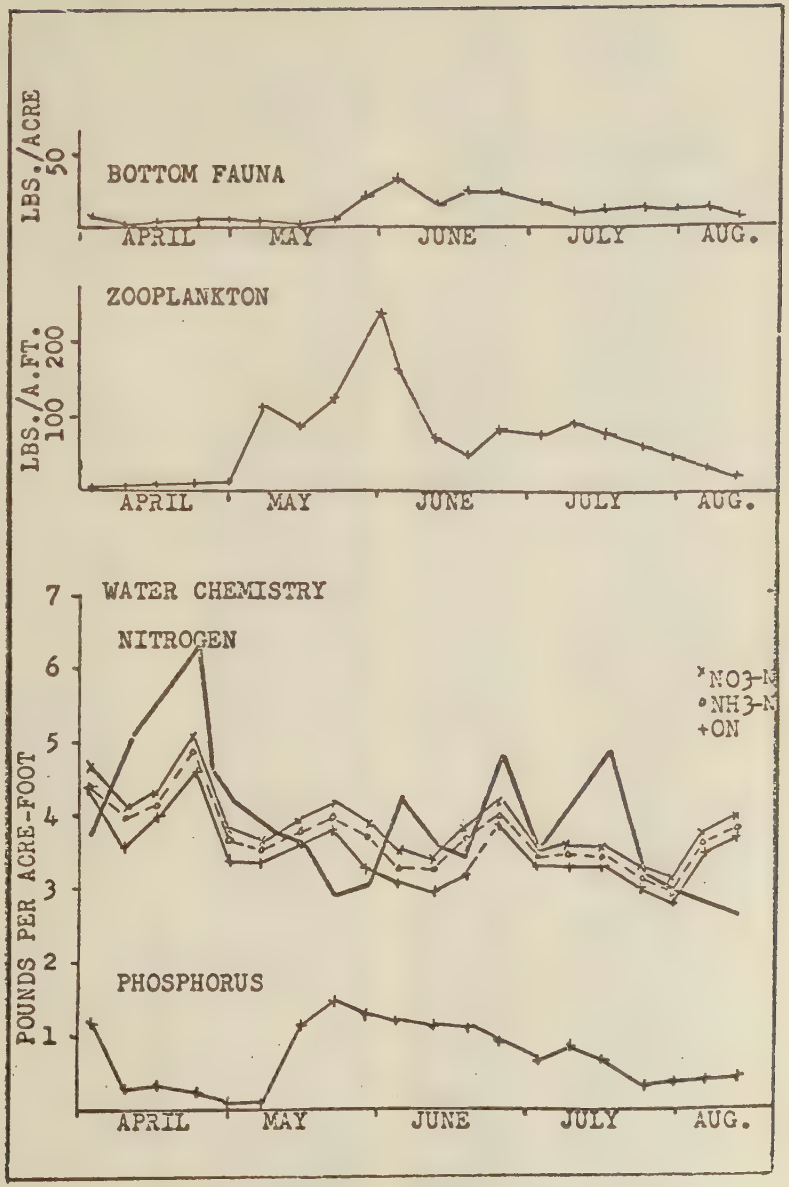

Fig. 6 Water chemistry, zooplankton and bottom fauna populations of Waterville experimental pond 5 which was fertilized with enough dried sheep manure to supply 6.0 pounds of nitrogen per acre foot of water in 1962.

filamentous algae which formed a good substratum for the production of a fairly large population of bottom fauna in July and August. Zooplankton populations were not any larger than those in the control ponds. A large percentage of the phosphorus was lost by precipitation to the soil by mid-summer. However, some of this phosphorus may be recycled in the following seasons.

Two ponds were fertilized with enough of the soluble muriate of potash to provide 1.6 kg of potassium per 1,000 m^3 of water. The pond water was not analyzed for potassium. The addition of this material had no measurable effect on either the nitrogen or phosphorus metabolism of the ponds or on the production of aquatic organisms.

Two ponds were treated with a trace element supplement containing manganese, iron, calcium, copper, zinc, iodine, cobalt and boron that is used in livestock feeds, and two were treated with the chelate Versonal 120. Neither of these treatments had a measurable effect on the general water chemistry or the biological populations in the ponds. The chelate when used alone had a dampening effect on pH which normally rises to high levels in mid-summer, but when used with dried sheep manure this effect was not noticeable.

2.2 Organic fertilizers

Dried sheep manure was used as the principal organic fertilizer in these studies, because it is similar to the barnyard manures that are used for fertilizing the large walleye ponds but is more uniform in chemical composition than barnyard manure. Two ponds were fertilized with enough dried sheep manure in April to add 2.2 kg of nitrogen per 1,000 m^3 of water. Throughout the entire study these ponds produced large populations of microcrustaceans in May and June and moderate-sized populations in July and August (Fig. 6). Bottom fauna production was fairly high in June. Dried sheep manure decomposes slowly and fertilization at this rate had no noticeable effect on the nitrogen content of the pond water either immediately or later. However, large amounts of phosphorus were released into the water within a few hours after the application of the manure and large mats of filamentous algae developed a few weeks later.

Dried sheep manure was also used at rates whereby 1.1, 3.3 and 4.4 kg of nitrogen were added per 1,000 m^3 of water. Populations of microcrustaceans and bottom fauna from these applications were similar to those produced by the standard rate of 2.2 kg of nitrogen per 1,000 m^3 of water. Only the highest rate of fertilization (4.4 kg) contributed a noticeable amount of nitrogen to the pond water. Release of phosphorus was proportionate to the amount of fertilizer used. Fertilization with enough dried sheep manure to provide 1.1 kg of nitrogen per 1,000 m^3 seems to be the most practical of the four rates because production of animal plankton and benthic organisms was as good as with heavier rates of application and release of phosphorus was lowest.

The fertilizers used so far in this study were applied to the pond waters to supply organic materials and other nutrients to directly or indirectly feed bacteria that would be food for microcrustaceans. In May and June these materials were very effective in producing large populations of cladocerans. Such cladocerans can strain bacteria from pond waters for food. However, in July and August materials released from manures were not effective in producing sizeable populations of copepods, probably because these animals require food organisms large enough to be caught by clasping. Therefore, the operational plan was altered to include weekly applications of yeast, which, it was hoped would supply particles large enough to be eaten by most copepods.

Two ponds were treated with weekly applications of brewer's yeast at the rate of 112 kg per ha starting in April. These applications resulted in a very large population of cladocerans in May and June but, contrary to expectations, produced only small populations of copepods in July and August (Fig. 7). Bottom fauna populations were large throughout summer and were better than those produced by any other method of fertilization. The yeast had no measurable effect on the organic content of the water, but phosphorus concentrations increased gradually through the season.

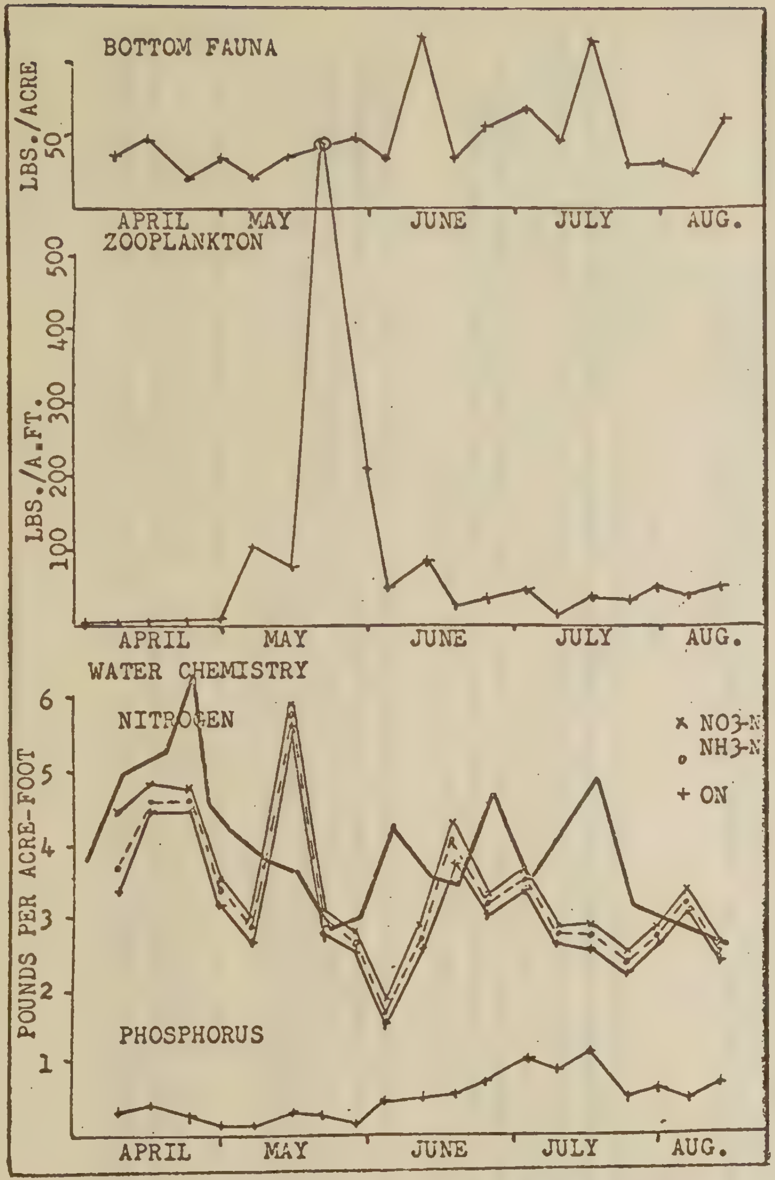

Fig. 7 Water chemistry, zooplankton, and bottom fauna populations of Waterville experimental pond 1 which was fertilized with brewer's yeast at the rate of 100 pounds per acre per week for 15 weeks in 1962.

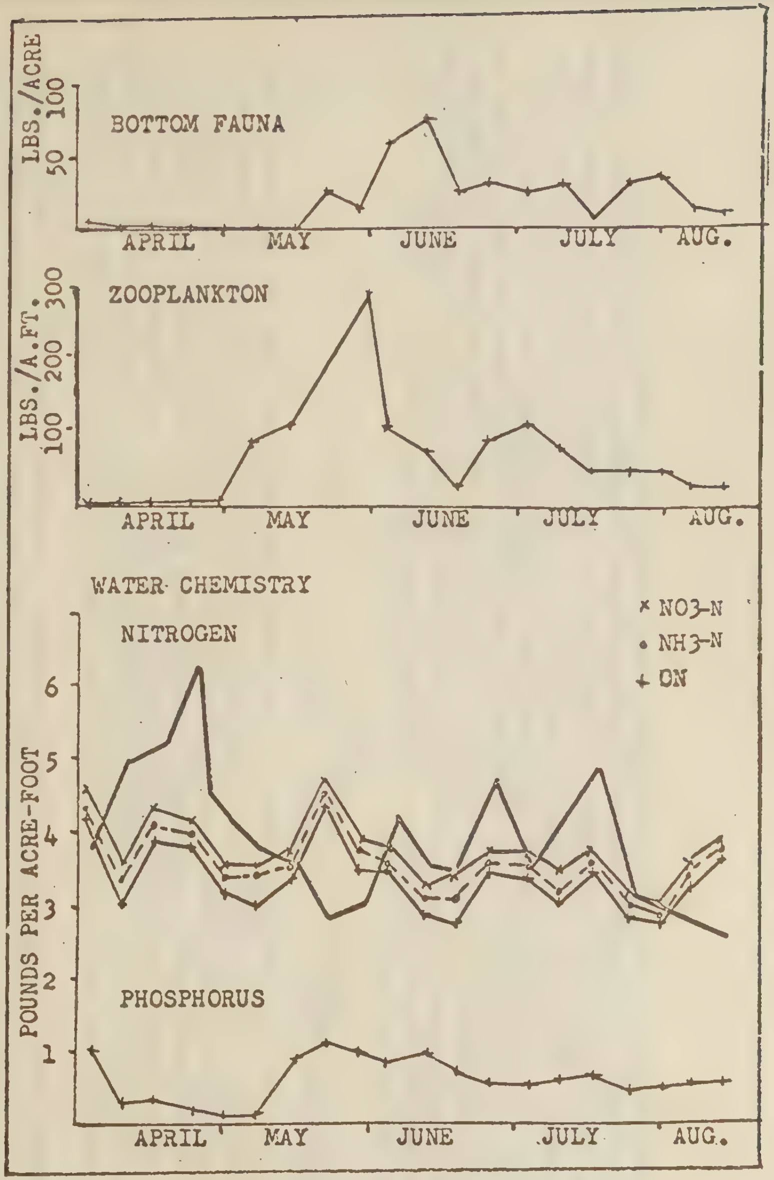

Fig. 8 Water chemistry, zooplankton, and bottom fauna populations of Waterville experimental pond 2 which was fertilized with enough dried sheep manure to provide 6.0 pounds of nitrogen per acre-foot of water and 9 weekly applications (100 pounds per acre each week of brewer's yeast starting June 15, 1962.

Two other ponds were fertilized in April with dried sheep manure at the standard rate (2.2 kg N/1,000 M^3) to produce a suitable population of cladocerans in May and June. Weekly applications (112 kg/ha) of brewer's yeast were started on June 15 as the cladoceran populations declined. With this treatment a good-sized crop of copepods appeared in late June and July (Fig. 8). The combination also resulted in large bottom fauna populations from May to August. Contribution to the nitrogen concentration of the water was negligible, but the release of phosphorus was much greater than desirable. This manure yeast combination produced the best seasonal distribution of animal plankton and benthic populations obtained from any of the fertilization methods. Yeast produced the only definite increase in bottom organisms measured thus far.

2.3 "Green fallowing"

Fish ponds that are drained annually lose water and soil fertility and in them fish production declines. In Minnesota walleye rearing ponds fertilizers added to the water have had very little or no effect on soil fertility. Soil fertility can probably be increased by "green fallowing", a program whereby each pond is dried out occasionally, so the bottom can be planted with an agricultural crop which will be ploughed into the soil after it has matured and before the pond is refilled with water. The Waterville ponds will be planted with rye and soybeans for a five-year study of this method of soil enrichment.

Even though most fish ponds grow large amounts of aquatic vegetation it still seems desirable to raise crops of terrestrial vegetation on the pond bottoms because these plants offer a better form of soil enrichment than aquatic plants. Aquatic plants contain a higher percentage of water and, consequently, less nutrients than terrestrial plants. Of these nutrients, aquatic vegetation has higher percentage of phosphorus than terrestrial vegetation. Roots of terrestrial vegetation penetrate farther into the soil than those of aquatic plants. Mineralization of bottom deposits during the period when the pond is dry is also beneficial in that it releases nutrients bound in the sediments.

3 SUMMARY

In Waterville, Minnesota, U.S.A., several kinds, types, and concentrations of fertilizers have been added to ponds to produce fish food organisms, and the effects of these on pond chemistry and production have been measured. Inorganic salts of nitrogen, phosphorus, and potassium added to the pond waters were not effective alone in increasing the size of zooplankton populations. Phosphate fertilizers produced dense mats of filamentous algae that formed a good substratum for insect growth, but this also resulted in heavy algal growths that were a nuisance in the management of the ponds.

Organic fertilizers (dried sheep manure and yeast) were more effective in increasing the size of animal plankton and benthos populations. A combination of dried sheep manure and brewer's yeast provided the best production of microcrustaceans and insects throughout the summer. However, release of phosphorus by these fertilizers was enough to produce nuisance populations of algae or aquatic vegetation.

Green fallowing of the bottom soils of drained ponds will be tried and may prove to be the most practical method of increasing zooplankton and benthos populations during the last half of summer without producing nuisance problems. This has possibilities because the terrestrial vegetation which is incorporated into the soil by this method is comparatively low in phosphorus.

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ECONOMIC ASPECTS OF FISH FEEDING IN THE NEAR EAST

by

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Abstract

Feeding of fish on a commercial fish farm is economically feasible only when the farm is over about 20 ha in area. Because of high investments, fish culture is economic only if high fish yields can be obtained by the addition of feed. The cost of production per ton of fed fish is much lower than that of unfed fish.

A balanced diet formulated with due consideration of the natural food in the ponds may bring good returns in carp yield. If it gives good results it should be economically analysed, and the "break-even" price of the feed be ascertained, before its commercial use.

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ASPECTS ECONOMIQUES DE L'ALIMENTATION DES POISSONS EN MOYEN-ORIENT

Résumé

L'alimentation du poisson dans un établissement piscicole commercial ne présente un intérêt économique que lorsque l'exploitation a une superficie supérieure à une vingtaine d'hectares. En raison de l'importance des investissements nécessaires, la pisciculture n'est rentable que s'il est possible d'obtenir un rendement élevé grâce à l'alimentation artificielle. Le prix de revient de la tonne de poisson alimenté artificiellement est beaucoup plus faible que celui du poisson n'ayant reçu aucun supplément d'alimentation.

Un régime équilibré, établi compte dûment tenu des aliments naturels existant dans les étangs, peut fournir un rapport appréciable en carpiculture. Si les résultats sont bons, il y a lieu de procéder à une analyse économique de manière à calculer le prix-seuil de rentabilité des produits alimentaires utilisés avant de procéder à une exploitation commerciale.

ASPECTOS ECONOMICOS DE LA ALIMENTACION DE LOS PECES EN EL MEDIO ORIENTE

Extracto

La alimentación de peces en una granja piscícola de tipo industrial es factible económicamente sólo cuando la granja tiene más de 20 hectáreas de extensión. Dadas las grandes inversiones de capital que precisa la piscicultura ésta sólo es económica si se pueden obtener elevados rendimientos de peces mediante la adición de alimentos. El coste de producción por tonelada de pescado alimentado es mucho menor que la del pescado sin alimentación adicional.

Una dieta equilibrada formulada teniendo debidamente en cuenta el alimento natural existente en los estanques, puede dar buenos beneficios en el rendimiento de la carpa. Si da buenos resultados deberá analizarse económicamente y averiguarse el precio del alimento que no determine pérdidas, antes de su empleo comercial.

1 INTRODUCTION

Before attempting an analysis of the economic aspects of fish feeding, the term should first be clearly defined. For the purpose of this paper fish feeding means feeding of warm-water fishes (mainly carp, Cyprinus carpio) cultured in ponds for human consumption on a commercial scale. These fish farms are self supporting economic units, not subsidized by the government in any way, and which produce fish at a price competitive with fish or other animal products.

This definition excludes from the scope of this paper small farm ponds or home ponds, which are found in many countries (though not in Israel). Fish feeding can be economical only when special care is taken to ensure the constant supply of feed and its daily routine application to the ponds. This is only feasible when the fish farm is above a minimum size, which seems to be about 20 hectares. It is possible, of course, that in some cases a smaller pond area may be successfully incorporated into a larger mixed agricultural farm where the pond management is efficient and organized well enough so that the fish will be regularly fed with good results. These cases, however, are few and exceptional.

In this connection it should be remembered that the general trend in agricultural techniques today is toward bigger farm units, where modern methods and equipment can be better utilized.

2 FEEDING WITH REGULAR FEED STUFFS

The first question to be answered when considering feeding fish in ponds is whether it is economic. This question may be put in a more extreme form: is fish culture economic without feeding? i.e., would fish yield from fish farms based on the pond's natural food alone (with or without fertilization) cover both capital and running costs, and still leave some profit for the owner? From the analyses given below it seems that, except for a few very fertile ponds, the answer is usually negative.

The fixed costs in fish culture are so high that they can be covered only by high fish yields. The invested capital for building of the ponds and the water system (which in Israel is about $2,000 per hectare), capital invested in gear, and costs of water, fertilizers, etc., are almost the same whether the fish are fed or not. There is some difference in labour costs, which are higher when fish are fed. This difference, however, is not proportional to the increase in yield obtained by feeding. The result is that the costs per ton of fish yield are higher without feeding than with feeding of the fish.

The average fish yield in Israel, in ponds where fish are fed, is 2,100 kg/ha, whereas in ponds without feeding (though fertilized) it is only 800-1,000 kg/ha. To obtain this increased yield, different feeds were used, such as certain cereal grains and oil cakes. The relative feeding coefficient, i.e. the amount of feed in kg per 1 kg of fish yield, is dependent on several factors such as the productivity of the pond and the feed used. In most cases, however, the average feeding coefficient was 2.5 - 3 for carp up to 600 g. Taking these data as a basis, the costs per unit area and per ton of fish were calculated for the two methods of culture, with and without feeding (Table I). The comparison between the costs per ton of fish cultured with feeding and that cultured on natural food alone, clearly shows that, in Israel commercial fish culture without feeding is uneconomical.

3 FEEDING WITH A BALANCED DIET

For some time it has been felt that progress in the feeding of carp is lagging behind the advancement in feeding of trout, salmon, and farm animals. In all these cases feeding of balanced diets has resulted in a considerable increase in yields. One should expect,

Table I

Calculation of costs per hectare and per ton of fish cultured in Israel with and without feeding

	With feeding		Without feeding	
	Per ha	Per ton	Per ha	Per ton
Yield per hectare	2,100 kg	-	1,000 kg	-
(Hectare per ton)	-	(0.47)	-	(1.0)
Costs				
Charges for capital invested in ponds and fishing gear	$ 360	$ 169	$ 360	$ 360
Water	210	99	210	210
Fertilizers	87	41	87	87
Maintenance	106	50	106	106
Feed	370	174	-	-
Labour	286	116	150	150
Marketing costs	32	15	12	12
Interest on working capital	5	2	2	2
General and overhead expenses	10	5	8	8
Total	$1,466	$ 671	$ 935	$ 935

Table II

Calculation of the break-even price for protein-rich feed, when the increase in yield is 20 percent, and for conditions in Israel

	Amounts	Costs per ha	Costs per ton
Yield per hectare	2,500 kg		
(Hectare per ton)	(0.4 ha)		
Total costs using regular feed (Table I)		$ 1,466	$ 671
Additional costs of labour, marketing, etc., due to increased yield		4	
Costs of regular feed for yield above 'critical point' (700 kg yield) X 2.5 (Relative feeding coeff.)	1,750 kg/ha	-100	
Total costs without protein-rich feed		1,370	548
Difference in cost per ton yield			123
Protein-rich feed needed per ha when fed above the 'critical point' 1,100 kg yield X 2.5 (Relative feeding coefficient)	2,750 kg		
Protein-rich feed needed per ton of yield (2,750 x 0.4)	1,100 kg		
Break-even price for protein-rich feed		$\frac{\$ 123}{1,100 \text{ kg}}$	= $ 112 per ton

therefore, that feeding carp a balanced diet would have a similar effect. This assumption gives rise to the following questions: (a) Considering that natural food is an important part of carp food, would feeding with a balanced diet cause an increase in yield or a lowering of the feeding coefficient? (b) What should be the composition and the price of such a diet? (c) Would the feeding of this diet be economical, i.e. would the gain in fish yield cover the added cost of feed, which would undoubtedly be higher than that of regular feeds used today? Some answers to these questions may be found in the results of experiments on carp feeding carried out in Europe (Janeček and Janeček, 1961; Merla, 1963; Müller and Merla, 1964; Kapach, personal communication) and in Israel (Hepher and Chervinski, 1965).

From these works it is clear that natural food is an important factor in the growth of carp in ponds. It would be a mistake, economically, to neglect this food which has qualitative as well as quantitative values. The protein and other nutrients in the natural food should be taken into consideration, and the supplementary diet added in such a way as to balance the natural food.

The protein content in natural food is very high, reaching about 60 percent of its dry matter (Schäperclaus, 1961; Mann, 1961). When natural food alone is utilized by the fish, part of this high quality protein is converted into energy. This source of energy could be provided even better by the carbohydrates in added feed, e.g. cereal grains. The protein in the natural food will thus be released to provide for further fish growth.

It is evident, therefore, that when natural food is abundant in the pond, a protein-rich diet would not have any advantage over cereal grain feeding. This was clearly shown in Hepher and Chervinski's experiments, where there was no effect of such a diet on yield when fish were small and their standing crop in the pond had not reached a "critical point" of about 800-1,100 kg/ha.

The situation is different, however, when the fish grow larger and their standing crop exceeds the "critical point". (This point may be different in different ponds, according to conditions). The need for protein then increases, while its supply decreases. A shortage in protein develops, and it is at this point that the protein-rich diet affects yields. When fish are fed at this stage with a protein-rich diet their growth rate remains as before, or even increases, whereas when they are fed with cereal grains there is some growth inhibition, probably due to shortage in protein. The increase in yield achieved in Hepher and Chervinski's experiments was about 20 - 50 percent over the whole growing season.

It is possible to calculate the "break-even price" for the protein-rich feed, above which feeding with this feed is not economical, as returns in fish yield would not cover the additional cost for feed. Such a calculation for Israel conditions is given in Table II. Here the increase in yield due to feeding with protein-rich diet was taken as 20 percent only, though in some cases the differences in yield were greater. It should be remembered that in Israel the average yield of 2,100 kg/ha is attained in two growing seasons, each season of about 120 days giving about half of the yearly yield. Of this yearly yield, about 1,400 kg/ha (700 x 2) is received when the standing stock is still below the "critical point", whereas the rest (about 700 kg/ha) is received when the fish are bigger and the standing stock is over the "critical point".

According to Table II the "break-even price" is $112 per ton of protein-rich feed, when the yield increase is 20 percent. Obviously, if the price is higher, or the yield lower, it will not be economic. Such an analysis should be made for any diet before introducing it for commercial use.

In conclusion it can be said that new diets may result in higher yields of fish, just as they do in other farm animals. This justifies more basic, large-scale study of the subject. The results of this study, however, before being applied commercially, should be examined critically from the economic point of view.

4 REFERENCES

Hepher, B. and J. Chervinski, Studies on carp nutrition - the influence of protein-rich
1965 diets on growth. Bamidgeh, 17(2):31-46

Janeček, V. and V. Janeček, On the significance of percental presence of some proteinaceous
1961 and carbohydrate-containing feedstuffs in feed mixture for carp with utilization of so-called surrogate feedstuffs. Pr.VÚRH Vodňany, (1):48-72

Mann, H., Fish cultivation in Europe. In Fish as food, ed. by G. Borgstrom, London, Aca-
1961 demic Press, pp. 77-102

Merla, G., Die Rolle der Naturnahrung als Eiweissquelle bei der Erzielung von Karpfen-
1963 erträgen. Dtsch.Fisch.-Ztg., 10(3):77-82

Müller, W. and G. Merla, Die Bedeutung des Eiweissgehaltes der Karpfenfuttermittel für
1964 den Karpfenabwachs unter Intensivbedingungen. Dtsch.Fisch.-Ztg., 11(9):273-7

Schäperclaus, W., Lehrbuch der Teichwirtschaft. Berlin, Paul Parey, 582 p.
1961

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FEEDS AND FEEDING OF WARM-WATER FISHES IN PONDS IN ASIA AND THE FAR EAST

by

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Abstract

To produce food as economically as possible, the centuries-old art of fish culture in Asia and the Far East has been developed on the basis of using a number of compatible non-predatory fish species that are able to make the best use of all natural food.

Supplementary feeding is practised for rapid growth of fish and for permitting high intensity of stocking.

Green manure and animal manure are the principal fertilizers used for the promotion and maintenance of a rich growth of natural food.

Artificial feeds used include a large variety of materials of both plant and animal origin, which can be obtained easily either without cost or cheaply. Chemical composition and food quotients of the principal kinds of feed are listed.

Rearing of fish fry and fingerlings is always done with great care to provide a rich supply of natural food and the daily application of supplementary feeds. Young fry of all pond fish of this region require high amounts of animal food.

Success in Chanos culture depends mostly on the maintenance of a rich supply of natural food: principally filamentous blue-green algae and diatoms.

Large fresh-water ponds with small fish populations are seldom fertilized and supplementary feed is very rarely given. In ponds of medium size with varied intensity of stocking, treatments range from no fertilizing and no supplementary feeding to heavy fertilization and heavy feeding, with many gradations in between. In ponds with high intensity of stocking, especially when several kinds of fish of different food habits are cultured together, heavy fertilization and ample supplementary feeding are always practised. Intensive feeding with artificial feed alone is done only in small ponds, mostly with running water, with extremely high stocking intensity.

L'ALIMENTATION DES POISSONS EN ETANGS A TEMPERATURE ELEVEE EN ASIE ET EN EXTREME-ORIENT

Résumé

Pour assurer une production alimentaire aussi économique que possible, l'art séculaire de la pisciculture est pratiqué en Asie et en Extrême-Orient selon un système qui associe diverses espèces compatibles et non prédatrices, aptes à tirer le meilleur parti possible de tous les aliments naturels.

Une alimentation d'appoint est fournie lorsque l'on veut accélérer la croissance des sujets d'élevage et maintenir une forte densité d'empoissonnement.

L'engrais vert et le fumier animal sont les principaux moyens utilisés pour favoriser une croissance abondante d'aliments naturels.

Pour l'alimentation artificielle, on puise dans une large gamme de produits, d'origine tant végétale qu'animale, qu'il est facile d'obtenir à peu de frais ou gratuitement. La composition chimique et le quotient nutritif des principales sortes d'aliments sont indiqués.

Lors de l'élevage des alevins et des jeunes poissons, on prend toujours grand soin de leur fournir une alimentation naturelle abondante et une ration quotidienne d'appoint. Les alevins de toutes les espèces de poissons élevés en étangs dans cette région exigent une forte quantité d'aliments d'origine animale.

L'élevage du Chanos ne peut s'effectuer avec succès qu'à condition d'assurer une grande abondance d'aliments naturels, notamment algues bleues filamenteuses et diatomées.

Les grands étangs d'eau douce à faible densité de peuplement sont rarement traités aux engrais et il est tout à fait exceptionnel que l'on y déverse des aliments d'appoint. Dans les étangs de taille moyenne, où la densité d'empoissonnement varie, les pratiques sont multiples : dans certains on n'ajoute ni engrais ni aliments supplémentaires, tandis que d'autres reçoivent de fortes doses d'engrais et d'aliments artificiels; enfin, entre ces deux extrêmes, on observe toute une variété de traitements. Dans les étangs fortement peuplés, notamment là où sont élevées ensemble plusieurs espèces de poissons ayant des habitudes alimentaires différentes, on a toujours recours à une fertilisation importante et à une abondante alimentation d'appoint. L'alimentation intensive, à base uniquement de nourriture artificielle, ne se pratique que dans les petits étangs, en général à eau courante, ayant une densité d'empoissonnement extrêmement élevée.

ESTUDIO SOBRE LOS ALIMENTOS Y LA ALIMENTACION DE LOS PECES DE AGUAS TEMPLADAS EN LOS ESTANQUES DE ASIA Y EL LEJANO ORIENTE

Extracto

Con objeto de producir alimentos lo más económicamente posible, el arte milenario de la piscicultura en Asia y el Lejano Oriente se ha desarrollado basándose en el empleo de cierto número de especies piscícolas no predatorias compatibles entre sí y capaces de aprovechar bien todos los alimentos naturales.

Se lleva a cabo una alimentación suplementaria para que los peces crezcan rápidamente y obtener una elevada densidad de población.

Los principales fertilizantes que se emplean para el fomento y conservación de un rico crecimiento de los alimentos naturales son el abono verde y el de origen animal.

Los alimentos artificiales empleados comprenden una gran variedad de materias de origen vegetal y animal, las cuales se pueden obtener con facilidad, sin gastos o a bajo costo. Se indica la composición química y los cocientes alimentarios de las principales clases de alimentos.

La cría de los jaramugos y de los pececillos se hace siempre con el mayor cuidado para facilitar un suministro rico de alimento natural así como la aplicación cotidiana de alimentos suplementarios. Los jaramugos de todos los estanques piscícolas de esta región exigen grandes cantidades de alimento de origen animal.

El éxito del cultivo de Chanos depende, sobre todo, de la conservación de un rico suministro de alimento natural: principalmente algas filamentosas verde - azules y diatomeas.

Los grandes estanques de agua dulce en los que viven pequeñas poblaciones piscícolas, se fertilizan pocas veces y muy raramente se da un alimento suplementario. En los estanques de tamaño con una intensidad variada de población, los tratamientos comprenden desde el no fertilizar y no dar alimentación suplementaria hasta una gran fertilización y una gran alimentación suplementaria, con amplias gradaciones. En los estanques con intensidad elevada de población, especialmente cuando se cultivan juntas varias clases de peces de diferentes hábitos alimentarios, se practican siempre una gran fertilización y una amplia alimentación suplementaria. La alimentación intensiva, exclusivamente con alimentos artificiales se hace sólo en pequeños estanques, en su mayoría de agua corriente, con una intensidad de población extremamente elevada.

1 INTRODUCTION

Fish culture in Asia and the Far East has a history of over 2,000 years and has been developed, with few exceptions, on the basis of using an association of a number of compatible non-predatory fish of different but complementary food habits, cultured together to make the best use of all the natural food material present in the pond. To accelerate fish growth, and also to permit increased stocking rate, many kinds of supplementary feeds are used.

Techniques for intensive feeding have been developed and applied in extremely heavily stocked ponds where the growth of fish depends entirely upon artificial feed, and the ponds serve merely as holding places for the fish.

Research on (i) the application of various types of fertilizers for promoting growth and increasing production of natural food, (ii) analyses of chemical composition and food value of various artificial feeds, (iii) feeding experiments, etc. have been conducted by many of the countries of this region. However, the exact dietary requirements of many of the common pond fish are not well known, and there is little scientific information on how to promote and maintain a rich growth of natural food. Study is also needed on the optimum amounts of food, both natural and artificial, required for maintenance and growth by different species of pond fish at different stages in their life history, intensities of stocking, and under varied environmental conditions.

2 FISH FOOD

2.1 Natural food

Since fishes of different food habits are cultured, practically all the plants and animals that grow naturally in the pond, except some of the tougher higher plants and large vertebrate animals, can be consumed as natural food. To promote growth of natural food, application of green manure, animal manure, agricultural by-products and, recently, inorganic fertilizers are used.

Green manure includes all types of tender plant leaves and stems that are rich in protein, such as odoriferous plants and legumes, that can either be collected from the field without cost or can be obtained very cheaply. Agricultural by-products include rice bran, soybean cake, oil-seed cake, grain husks, paddy straw, bean pods, etc. Animal manure includes cow dung, pig dung, goat dung, chicken droppings, duck droppings, silkworm droppings, human night soil, etc. In some cases animal sheds and fowl coops are built on the banks, or close to fish ponds so that the droppings can be washed into the ponds daily.

2.2 Artificial feeds

A large number of materials of plant and animal origin have been used as artificial feed. The criteria for the selection of artificial feed are (i) acceptability to fish, (ii) effectiveness in promoting fish growth and (iii) degree of cheapness and availability.

2.2.1 Feeds of animal origin

These include aquatic earthworms, land earthworms, clams, snails, daphnids, copepods, Mysis, small shrimps, small crabs, insect larvae, locusts, silkworm pupae, white ants, midges and other aquatic insects, trash fish, fish meal, fish entrails, entrails from slaughter house and food processing plants, meat, blood, liver and spleen, etc. Certain amounts of animal manures used as fertilizers are always consumed by fish directly as food.

2.2.2 Feeds of plant origin

These include green fodder such as Ipomaea reptans, land grass, sweet potato leaves, tapioca leaves, bean leaves, banana leaves; roots such as sweet potato, potato, tapioca; seeds such as peanuts, soybean, broad bean; cereals such as rice, wheat, barley, oats, maize and their bran, flour and meal; meal and oilcake of peanut, cotton seed, mustard seed, coconut; soybean milk, soybean refuse, mill sweepings, brewer's refuse; aquatic plants such as Wolffia, duck weeds, Spirodela, Azolla, Salvinia, Eichhornia, Pistia, Hydrilla, Najas, Potamogeton, Myriophyllum, Ceratophyllum; algae such as Oscillatoria, Lyngbia, Phormidium, Spirulina, Chaetomorpha, Entermorpha, Gracilaria, etc.

2.2.3 Chemical composition and food quotient

The chemical composition (percentage of protein, fat and carbohydrate) and food quotient of some of the common artificial fish feeds are given in Tables I and II.

3 FOOD AND FEEDING

Three main categories of fish culture operations are practised in this region: (i) those that depend on natural food entirely, (ii) those that depend on both natural food and supplementary feeding, and (iii) those that depend entirely on intensive feeding of food introduced from outside the pond.

Generally speaking, the first category includes ponds of large size of over four ha (except milkfish[1] ponds), such as converted farm-water reservoirs, converted small swamps, bunded shallow areas of lakes or coastal flats, converted mining pools, rice fields, etc; the second category includes ponds of medium size heavily stocked with fish; and the third includes ponds of small size, mostly provided with running water, and always extremely heavily stocked with fish.

The growth of natural food in large ponds depends on the nutrients present in the pond soil and those carried in by the water, and fertilizers are applied occasionally, if used at all. A rich supply of natural food in ponds of the second category is maintained by heavy application of fertilizers at regular intervals. No fertilizer is used for ponds of the third category.

3.1 Rearing of fry and fingerlings

Rearing of fish fry and fingerlings has been developed into an industry in many countries of this region. Nursery ponds are carefully managed and well fertilized to produce rich growths of natural food, and supplementary feed of one kind or another is always given.

3.1.1 Culturing milkfish fry and fingerlings

Milkfish fry when collected from natural waters are delicate post-larvae of minute size. They are first kept for a few days in well protected "baby boxes" and are fed with either mashed hard boiled egg yolk, wheat starch or fine rice bran; then transferred to well prepared nursery ponds in which a rich growth of benthic micro-organisms, including blue-green algae, diatoms, protozoans, rotifers and other minute invertebrates has already started.

The fry feed readily on the minute natural food. When the supply of natural food is insufficient, fine rice bran, dried "lab-lab" and sometimes dried and ground submerged plants are used as supplementary feed, given either once or twice a day.

[1] Chanos chanos

Table I

The composition of some supplementary feeds for pond fish

	Composition in percentage by weight						
	Dry matter	Crude protein	Crude fat	Carbo-hydrates (Nitrogen free extract)	Crude fibre	Ash	True protein
Plant products							
1. Seeds & roots							
Soybean (China)	90.0	36.3	18.4	25.0	4.8	5.0	29.9
Rice - hulled (Malaya)	88.7	8.4	2.1	76.7	0.7	0.8	
Rice - broken (Malaya)	88.6	7.5	0.5	79.9	0.2	0.5	
Wheat (Europe)	87.0	12.2	1.9	69.3	1.9	1.7	11.0
Maize (China)	88.0	8.5	4.3	71.7	1.3	1.7	
" (Malaya)	86.2	8.8	4.3	70.4	1.3	1.4	
"- flaked (Europe)	89.0	9.8	4.3	72.5	1.5	0.9	9.4
Cotton seed (India)	91.0	17.8	19.3	29.7	19.9	4.3	16.5
Ground nut	94.0	26.8	44.9	17.5	2.6	2.2.	24.9
Oat (Europe)	87.0	10.4	4.8	58.4	10.3	3.1	9.5
Barley (Europe)	85.0	9.0	1.5	67.4	4.5	2.6	8.5
Broad bean - fresh (China)	23.0	9.0	0.7	12.0	0.3	1.2	
" " - dry (China)	87.4	28.2	0.8	49.0	6.7	2.7	
Potatoes	23.8	2.1	0.1	19.7	0.9	1.0	1.6
Sweet potatoes (Malaya)	25.4	1.3	0.1	22.7	0.8	0.5	
Sweet potatoes - fresh (China)	33.0	2.3	0.2	29.0	0.5	0.9	
" " - dry (China)	87.0	6.1	0.5	77.0	1.4	2.4	
Tapioca - whole root (Malaya)	37.6	0.4	0.2	35.5	0.8	0.7	
" refuse, fresh (Malaya)	20.0	0.4	0.1	17.6	1.6	0.3	
2. Fresh plant material							
Duckweeds							
Lemna (China)	8.76	1.54	0.73	5.94		0.55	
Spirodela (China)	5.63	1.62	0.02	2.85	0.35	0.79	
Wolffia (China)	3.62	1.04	0.27	1.75		0.56	
Alternanthera philoxeroides (China)	22.50	3.22	0.30	11.92	2.62	4.44	
Eichhornia (China)	19.47	2.09	0.60	12.24		4.54	
" (Malaya)	5.9	1.0	0.1	2.4	1.2	1.2	
Pistia stratiotes (China)	4.84	0.17	0.26	2.53	0.58	1.30	
" (Malaya)	7.1	1.4	0.3	2.6	0.9	1.9	
Myriophyllum (Minnesota)	13.6	2.4	0.2	6.8	1.8	2.5	
Potamogeton (Minnesota)	22.7	3.3	0.4	10.5	4.9	3.7	
Ceratophyllum (Minnesota)	14.3	2.4	0.3	6.0	2.0	3.2	
Ipomaea reptans	7.5	2.1	0.2	2.9	0.9	1.4	
Sweet potato leaves & stem (Congo)	13.0	1.6	0.4	6.8	2.3	1.6	
" " vine (China)	12.4	2.08	0.67	5.96	2.43	1.26	
Tapioca leaves & stem (Malaya)	23.1	4.5	1.2	11.8	3.9	1.7	
Tapioca leaves (Congo)	27.3	8.8	0.9	6.2	9.8	1.7	

Table I (contd.)

The composition of some supplementary feeds for pond fish

	Composition in percentage by weight						
	Dry matter	Crude protein	Crude fat	Carbo-hydrates (Nitrogen free extract)	Crude fibre	Ash	True protein
Coco-yam leaves (Malaya)	12.1	2.3	0.7	6.1	1.4	1.6	
Pumpkin vine	17.5	1.5	0.90	7.7	5.6	2.9	
Rice stalk & leaves (dry)	94.02	3.76	0.81	41.9	32.9	14.65	
Corn stalk & leaves (dry)	90.6	5.9	1.6	46.6	30.7	5.6	
Guinea grass	23.0	2.9	0.2	10.3	6.6	3.0	
Roadside grasses (Malaya)	23.0	2.4	0.5	12.5	6.0	1.6	
Kudzu grass (Malaya)	19.1	3.8	0.4	7.9	5.5	1.5	
Maize leaves and immature cobs (Malaya)	20.1	3.0	0.6	12.2	2.5	1.7	
C. datylon (land grass)	22.4	4.89	0.78	10.40	4.17	2.0	
P. crusgallii (" ")	15.72	3.65	0.76	6.43	3.43	1.55	
3. Marine algae							
Filamentous blue-green (fresh, mixed)	9.85	2.32	0.21	1.52	0.70	5.11	
Oscillatoria spp.) *Phormidium* spp.) (wet)	17.10	1.65	0.39	1.37	1.46	12.23	
Diatoms (fresh, mixed)	12.87	2.89	0.94	2.25	0.27	6.52	
Phytoflagellates (fresh, mixed)	11.89	3.91	1.32	5.61	0.42	0.72	
Chaetomorpha							
Fresh	8.54	2.82	0.92	1.50	1.22	2.09	
Detrital form	10.72	3.46	0.38	3.21	0.98	2.69	
Enteromorpha intestinalis							
Fresh	18.65	3.66	0.48	8.49		6.02	
4. Oil cakes							
Soybean cake (China)	89.9	40.9	3.51	35.69	4.34	5.46	
Groundnut cake (China)	88.55	39.51	3.56	33.36	3.55	8.57	
" " (Malaya)	92.2	47.9	10.9	25.0	3.6	4.8	
Cotton seed cake (China)	91.3	36.58	4.99	33.41	8.31	8.01	
Coconut cake - single pressed (Malaya)	88.7	17.3	16.3	42.8	7.5	4.8	
Coconut cake	90.0	21.2	7.3	44.2	11.4	5.9	19.7
Palm kernel cake	89.0	19.2	6.0	46.5	13.4	3.9	18.1
- ditto - double pressed	89.0	13.1	10.0	54.9	7.7	3.3	
Mustard seed cake (China)	89.8	24.64	1.06	41.66	7.10	15.34	
5. Bran & meal							
Soybean oil meal	86.5	37.8	8.1	29.0	6.0	5.6	
Rice meal	89.0	11.3	11.7	44.3	12.9	8.8	
Rice bran (China)	89.0	13.68	17.9	37.02	6.84	13.56	
" " - fine (Malaya)	89.2	11.4	6.8	45.4	14.1	11.5	

Table I (contd.)

The composition of some supplementary feeds for pond fish

	Composition in percentage by weight						
	Dry matter	Crude protein	Crude fat	Carbo-hydrates (Nitrogen free extract	Crude fibre	Ash	True protein
Rice bran - coarse (Malaya)	90.5	6.2	2.7	37.8	33.1	10.7	
Cottonseed meal A	91.7	43.0	2.0	32.1	7.5	7.1	
" " B	88.4	34.4	5.8	28.9	13.0	6.3	
Wheat bran (China)	87.2	11.33	2.64	58.25	8.87	5.51	
" " (Europe)	85.1	15.0	3.2	54.1	7.5	5.3	
Cottonseed bran	92.6	3.38	0.91	46.14	37.01	5.23	
6. Miscellaneous							
Soybean curd residue	10.75	2.38	0.41	5.39	2.19	0.38	
Soybean refuse, fresh	14.1	5.5	0.7	5.8	1.6	0.5	
Sweet potato refuse	29.78	2.34	0.81	12.25	8.44	6.04	
Wheat refuse	29.8	6.54	3.24	12.74	4.23	3.05	
Rice refuse	20.33	5.59	3.21	9.29	1.10	1.14	
Paddy straw	94.0	3.76	0.81	41.9	32.9	14.65	
Corn leaves & stalk dried	90.6	5.9	1.6	46.6	30.7	5.6	
Peanut shell	90.9	7.3	2.6	18.9	56.6	5.5	
Broad bean shell	85.0	10.7	2.0	32.5	33.5	6.3	
" " pod	80.9	12.2	6.3	26.2	29.0	7.3	
Animal products							
Fish, fresh, trash (Malaya)	28.0	14.2	1.5	-	-	10.7	
Fish meal, white	87.0	61.0	3.5	1.5	-	21.0	57.0
Blood meal	86.0	81.0	0.8	1.5	-	2.7	71.9
Silkworm pupae, fresh	35.4	19.1	12.8	2.3	-	1.2	-
" " dried	90.0	55.9	24.5	6.6	-	1.9	-
" ", dried and defatted	91.1	75.4	1.8	8.4	-	5.6	-
River snail (whole)	63.20	5.70	0.70	2.00		54.8	
" " flesh	21.60	12.20	1.40	4.30		3.70	
Flesh of other snails	24.24	19.10	0.55			4.59	
Mussels - freshwater	20.40	18.40	0.80			1.20	
Small clams "	15.93	13.20	0.77			1.96	
Small shrimps	82.80	55.45	5.52	4.37		17.65	
Liver of cattle	25.0	21.2	0.6			1.0	
Gammarus	85.9	24.7	5.0			34.6	
Sardine meal	92.0	65.0	9.0			14.0	
Neomysis	66.7	35.0	7.0	5.2		19.0	
Aquatic worms	18.9	8.6	4.4			1.4	
Locust, fresh	34.1	25.5	2.0	1.4		2.2	
Chironomid, fresh	16.1	9.1	13.6			7.1	

Table II

Food quotients of some supplementary fish feeds

Feeds of animal origin		Feeds of plant origin	
Daphnids	4 - 6.4	Soybean	3 - 5
Mysis	2 - 3.9	Wheat flour	7.2
Gammarus	3.9 - 6.6	Barley flour	2.6
Prawn & shrimp	4 - 6	Corn	4 - 6.0
Earthworm (fresh)	8 - 10	Wheat bran	6.13 - 7.32
Clams (flesh)	1.3	Barley bran	7.0
Snail flesh-fresh	22.0	Irish potato	20 - 30
" " -dried	10.2	Cereals	4 - 6
Chironomids	2.3 - 4.4	Groundnut cake	2 - 4
Housefly maggots	7.1	Ground maize	3.5
Locust - fresh	10.7	Ground rice	4.5
" - dried	5	Oilpalm cake	6 - 12
Silkworm pupae - fresh	3 - 5	Manioc leaves	10 - 20
" " - dried	1.25 - 2.1	Manioc rind	50.7
		Manioc flakes	17.6
		Manioc flour	49.4
		Banana leaves	25.0
Fresh-water fish	4 - 8	Napier grass	48.0
Fresh sea fish (trash)	6 - 9		
Fish flour	1.5 - 3.0		
Fresh meat	5 - 8		
Meat flour	1.99 - 2.02		
Dried blood powder	1.51 - 1.68		
Liver, spleen	5.5 - 8.0		

Mixed diets	
Fresh sardine, mackerel, scad, dried silkworm pupae	5.5
Liver, sardine, silkworm pupae	4.5
Silkwork pupae, silkworm faeces, grass, soybean cake, pig manure, night soil	4 - 8
Raw silkworm pupae, pressed barley, *Lemna* and *Gammarus*	2.55 - 4
2/3 groundnut cake, 1/3 manioc leaves	3.5
½ manioc leaves, ½ ground rice	11.0
Manioc leaves and fresh manioc root	26.8
Fish flour, rice flour	2.5 -3.0
Meat flour, potato	3.5 - 4
Fresh silkworm pupae, wheat flour	10.4
Fish flour, soybean cake, yeast	1.7 - 2.8
Fish flour, cotton seed meal, yeast	1.56 - 3.4

Table III

Principal natural foods of Chinese carp fry

Size of fry - mm	grass carp	black carp	silver carp	big-head carp	common carp	mud carp
7 - 9	Protozoa, rotifer, nauplii	Protozoa, rotifer, nauplii	Protozoa, rotifer, nauplii	Protozoa, rotifer, nauplii,	Protozoa, rotifer, nauplii, Cladocera	Protozoa, rotifer, nauplii, Cladocera
10 - 12	Same as above, + small daphnids and Cyclops	Same as above, + small daphnids and Cyclops	Same as above, + small Cladocera	Same as above, + small Cladocera	Same as above and copepods	Same as above + diatoms, minute organic detritus
13 - 17	daphnids, copepods, minute benthic animals	Large daphnids, minute benthic animals	"	"	"	Minute organic detritus, diatoms, phytoplankton
18 - 23	Same as above, + organic detritus	Same as above, organic detritus	Same as above, + phytoplankton	Same as above, + phytoplankton, zooplankton	Cladocera, copepods, minute benthic animals	"
24 - 30	Same as above, + phytoplankton, minute algae	Same as above, minute benthic animals, insect larvae	Mostly phytoplankton	zooplankton, phytoplankton	Same as above + insect larvae, organic detritus	Same as above, small blue-green algae, minute benthic flora

3.1.2 Culturing fry and fingerlings of Indian carps [1] in India and Pakistan

Small seasonal ponds are generally used as nurseries. The pond bottom is dried, ploughed, levelled and then well fertilized and refilled with water. In a nursery pond of 0.4 ha, 3,125,000 fry can be reared for 12-15 days. The rich plankton produced provides the necessary natural food. Early fry prefer zooplankton. Rice bran, coconut oil-cake, mustard oil-cake and groundnut oil-cake, are often used as supplementary feeds. The oil-cakes are always given in finely powdered form.

Fry fed on oil-cakes in quantities not exceeding the following grow very well:

1st five-day period after stocking	artificial feed equal in weight to that of fry stocked
2nd five-day period after stocking	twice the weight of fry at the time of stocking
3rd five-day period after stocking	three times the weight of fry at the time of stocking

3.1.3 Culturing of fry and fingerlings of Chinese carps [2]

This is usually divided into two separate operations: (i) rearing of young fry to advanced fry, and (ii) rearing of advanced fry to advanced fingerlings.

3.1.3 (i) Rearing young fry to advanced fry

The average fry pond unit in China is about 1,000 m^2 in area and 0.8 m in depth. The prestocking preparations for each unit include (a) removal of surplus rich mud from the pond bottom, (b) sun drying the pond bottom, (c) application of quick lime (about 120 kg), (d) application of green manure (about 450 kg) and organic manure (cow dung 500 kg). Stocking is carried out after the caustic action of lime is completely over and a rich growth of natural food has developed.

To maintain a rich supply of natural food, an application of green manure (about 100 kg) and cow dung (about 30 kg) is made at about three-to five-day intervals. Supplementary feeds such as soybean milk, peanut cake, rice bran, etc. are given two to three times a day.

For rearing a batch of 150,000 fry, from young fry stage (averaging 0.8 cm/3 mg) to advanced fry (averaging 3 cm/1g) would take about 25 to 30 days. This would require a total amount of about 100 kg of soybean for making soybean milk as the principal supplementary feed or about 200 kg peanut cake if this is used. Soybean milk and peanut cake are often used together in various proportions according to personal preference of the farmer.

3.1.3 (ii) Rearing advanced fry to advanced fingerlings

Among the many types and variations practised, the method popular in Hong Kong is used as an example.

The prestocking preparation of the nursery pond is similar to that described above for rearing young fry. Peanut cake is used as the principal supplementary feed, and sometimes rice bran or soybean cake is also used.

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[1] Catla catla, Labeo rohita, and Cirrhina mrigala

[2] Ctenopharyngodon idella, Hypophthalmichthys molitrix, Aristichthys nobilis, and Cirrhina molitorella

A good nursery pond in Hong Kong has an average area of about 1,400 m^2 and one m depth, in which 50,000 advanced fry of three cm length can be stocked. It takes about 35 to 40 days for them to grow to 12 cm length (average wt 15 kg).

Rearing a batch of 10,000 fry of three cm size (total wt 10 kg) to advanced fingerlings of 12 cm (total wt 150 kg) will take about 40 days, and will require a total amount of about 150 kg of peanut cake. The daily amount of peanut cake used starts with about 1.5 kg and gradually increases to about 5 kg at the end of the rearing period.

3.2 Culturing fish in brackish-water ponds

3.2.1 Culturing milkfish

The milkfish feed mainly on filamentous blue-green algae (Cyanophyceae) and diatoms,(Bacillariophyceae). The blue-green algae eaten include *Oscillatoria*, *Lyngbya*, *Phormidium*, *Spirulina*, *Microcoleus*, etc. and the diatoms include *Navicula*, *Pleurosigma*, *Mastogloia*, *Stauroneis*, *Amphora*, *Nitzschia*, etc. A very rich growth of these algae occurs at the bottom of a good pond, forming a thick mat.

The filamentous green algae, *Chaetomorpha*, have a high food content, but when fresh these are relatively coarse and difficult to digest, therefore they are of little food value to the milkfish, especially to the fingerlings and young stages. However, after death and when softened by partial decomposition, *Chaetomorpha* detritus becomes good food for *Chanos*.

In Taiwan ponds when a rich growth of bottom algal pasture is maintained supplementary feed is only occasionally given. But supplementary feed, mainly rice bran, is always given when the bottom algal pasture is either insufficient for the fish, or is decreasing rapidly due to mismanagement or changes in environmental conditions.

In the Philippines, where ponds have less rich bottom algal pasture, supplementary feed such as rice bran is given. Algae collected from other water areas, the agar seaweed (*Gracilaria*), and even partially decomposed and softened common aquatic plants and paddy straw, are often used for feeding the fish.

In Indonesia rice bran is commonly used as supplementary feed.

3.2.2 Culturing grey mullets[1]

Grey mullets are cultured either in fresh-water ponds or in brackish-waters of low salinity. Their natural food consists mainly of unicellular and filamentous algae, diatoms, benthic algae, detritus and small pieces of soft vegetable matter. Small quantities of rice bran are generally used as supplemental feed in India and the Philippines. In Hong Kong and Taiwan ponds, where heavy stocking is done in combination with Chinese major carps, intensive feeding is practised mainly with rice bran and peanut meal, and sometimes with fine pieces of well soaked soybean cake. When pig manure and night soil are used for fertilizing ponds, some of this is consumed directly by the fish as food.

In a heavily stocked pond in Hong Kong the average stocking rate per ha of pond is about 10,000 mullets and 1,500 Chinese carps. An average of 3,500 kg net gain in fish weight can be expected in a growing period of 300 days. To produce this amount of fish the quantity of supplementary feeds necessary is about 2,500 kg of rice bran and 3,000 kg of peanut cake, besides the repeated application of animal manure at three to five day intervals. The feeding schedule for such a one ha pond is as follows:

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[1] *Mugil cephalus* and other species of *Mugil*

Number of days after stocking	Kind of feed	Average daily ration in kg
1 - 10	------	---------
11 - 30	rice bran	1.0 - 1.5
31 - 60	rice bran	1.5 - 3.0
16 - 90	rice bran	3.0 - 5.0
	peanut cake	2.0 - 5.0
91 - 150	rice bran	5.0 - 8.0
	peanut cake	5.0 - 10.0
151 - 210	rice bran	8.0 - 12.0
	peanut cake	10.0 - 16.0
211 - 300	rice bran	12.0 - 16.0
	peanut cake	16.0 - 24.0

3.2.3 Culturing prawns

In the Philippines and Taiwan, various species of penaeid prawn, P. monodon, P. japonicus, P. indicus, Metapenaeus ensis, etc. are cultured together with milkfish in brackish-water ponds. These prawns feed mainly on the worms and insect larvae which occur abundantly in the ponds but are not eaten by the milkfish. No supplemental feeding has yet been practised.

3.3 Culturing fish in fresh-water ponds

In Taiwan, as well as in other countries, fish ponds of over four ha, such as the reservoir fish ponds, are very seldom fertilized and no supplemental feed is given. Fertilizers are used in ponds below two ha, and feeding is done when stocking intensity is high.

The Chinese carps (grass carp, silver carp, bighead carp, mud carp), common carp (Cyprinus carpio), carassius carp (Carassius carassius), mullet and milkfish are cultured in various combinations and ratios. Mono-culture is also sometimes practised.

Grass, aquatic plants, duck weeds, banana leaves, vegetable waste, bean leaves, rice bran, peanut cake, soybean cake, wheat bran, trash fish, offals, blood meal, fish meal, earthworms, silkworm pupae, etc. are the principal materials used as feed.

When grass carp is cultured in combination with other fish, fresh tender plant material is used intensively. Green fodder is given usually twice a day by placing it within a floating feeding ring made of three or four bamboo poles. The amount of feed given per day has been estimated to be about 15-20 percent of the total weight of the fish fed. The fish farmer usually gives the quantity of fodder that will last for about an hour after each feeding. Grass carp excreta are often consumed by other carps directly as food. Other feeds are given roughly in the order of 7,000 kg agricultural products and 2,000 kg of animal products per ha per annum in heavily stocked ponds.

Feeding schedule for culture of mixed species*

(one ha pond, for producing 3,500 kg net wt of fish)

Months	Amounts of feeds - kg		
	Green fodder	Agricultural products	Animal products
March	50 (*Wolffia* or duck weed)	400	40
April	150 fodder	600	100
May	300 "	800	200
June	500 "	1000	300
July	1000 "	1200	500
August	2000 "	1200	500
September	3000 "	1000	300
October	4000 "	600	100
November	2000 "	400	-
	13100	7200	2040

*Stocking rate:- grass carp 250, silver carp & bighead carp 2000, mullet 3,000, milkfish 2,000, mud carp 1,000, common carp 500.

In mono-culture of common carp the feeding period lasts from February/March to November, and when mixed feed is used the proportion of plant to animal feed generally falls gradually from about 90 percent at the start to about 50 percent at the beginning of May. Pure animal material is then given from June until the end of August. Plant material is given again, increasing gradually from 50 percent at the beginning of September to about 90 percent about mid-November when feeding is discontinued.

For producing 1,000 kg of fish (net gain) about 1,500 kg of silkworm pupae or 7,000 kg of rice bran, or a mixture of 1,180 kg of pupae and 1,200 kg of rice bran is fed as follows:

Feeding schedule for mono-culture of common carp

(for producing 1,000 kg net wt of fish in one single harvesting)

Month	Amount of feeds - kg			
	Pupae alone	Rice bran alone	Pupae +	rice bran
March	80	400	20	200
April	120	600	40	250
May	160	800	100	300
June	200	1,200	200	-
July	300	1,500	300	-
August	300	1,000	300	-
September	240	1,000	200	250
October	100	500	20	200
	1,500	7,000	1,180	1,200

The large specimens of carp from such a mono-culture may, however, be harvested at the end of each culture period, the rest being left in the pond for further growth. When using silkworm pupae as feed, the feeding schedule would be as follows:

Feeding schedule for mono-culture of common carp

(Harvested in three instalments) [1]

Periods of culture	Fish in pond		Fish harvested		Pupae used kg
	Number	Total Wt. kg	Number	Total Wt. kg	
1st period					
Beginning of February	12,000	400			1,000
End of May	10,000	1,000	3,000	600	
2nd period					
Beginning of June	7,000	400			1,100
End of August	6,300	1,280	2,500	800	
3rd period					
Beginning of September	3,800	480			900
End of November	3,430	1,000	3,420	1,000	
Totals				2,400	3,000

In this case for 400 kg advanced fry stocked in February, the total harvest should be 2,400 kg, giving a net gain of 2,000 kg fish for 3,000 kg pupae used.

In Hong Kong, where grass carp, silver carp, bighead carp, common carp, mud carp, grey mullet (and sometimes black carp[2]) are stocked heavily in fresh-water ponds or ponds of very low salinity, heavy applications of fertilizers - green manure, animal manure and chemical fertilizers - are made for adequate production and maintenance of natural food. Intensive feeding is done with green fodders, vegetable wastes, aquatic plants, rice bran, peanut cake, soybean cake, sesame cake, wheat bran, etc., and when black carp is present snails, clams and earthworms are also used.

To maintain a constant daily supply of animal manure, which is also consumed by fish directly, ducks and pigs are kept in pens and sties built over or on the banks of the ponds. About 100 pigs (average size 30 kg) or about 2,500 ducks (average weight one kg each) are sufficient for producing animal manure required for one ha pond.

In Malaysia and Singapore there are two major types of fish culture, (i) using the association of Chinese carps, and (ii) using Puntius, Trichogaster, common carp and Tilapia.

For the first type, the feeds and feeding methods are very similar to those practised in South China, Taiwan and Hong Kong, but with more extensive use of animal manure.

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[1] Pond size about 5,000 m^2

[2] Mylopharyngodon piceus

For the second type, feeds and feeding are also based on Chinese practise, but feeds of animal origin, except manure, are seldom used.

In Thailand also the culturing of Chinese carps is based on Chinese methods, but feeds used are mainly of plant origin, except in North Thailand where white ants are often used for feeding common carp. For Tilapia, Trichogaster, Helostoma, Puntius and Osphronemus, cooked rice bran, broken rice, corn meal, Ipomaea, duck weeds, aquatic vegetation and land fodders are used. Feeds for Pangasius consist mainly of mixtures of rice bran, cooked broken rice, chopped Ipomaea, aquatic vegetation and trash fish. The catfish, Clarias, is fed principally with trash fish and animal offal.

In the Philippines, although fish stocking is extensive, fish culture in freshwater ponds is not yet popularly practised. For feeding Ophicephalus and Clarias, trash fish and small shrimps are used, and for carps and other non-predatory fish, rice bran, peanut cake and green fodder.

In Indonesia where Puntius, Tilapia, Helostoma, common carp, Osteochilus, Chanos and Osphronemus are cultured in ponds or in the rice fields, (in most cases only to relatively small sized fish), the main emphasis is on the application of fertilizers for producing natural food. Supplementary feeds given are rice bran, peanut meal, coconut meal, aquatic plants and land fodder.

In Cambodia, Pangasius are fed with the same kinds of feeds used in Thailand.

In Vietnam, common carp are mostly fed with rice bran and peanut meal.

In India and Pakistan where a number of Indian carps are extensively cultured, the emphasis is on production of natural food by the application of green and animal manure. Rice bran, oil-seed cake and groundnut cake are the principal artificial feeds given. Where Chinese grass carp is cultured, a large variety of aquatic vegetation and green fodder is used.

In Ceylon, rice bran, coconut cake and groundnut cake are the main kinds of fish feeds.

In Mainland China, the common practice of intensive stocking and heavy feeding has been further developed. It has been reported that during recent years with increased stocking rate (repeated heavy stocking of different kinds of fish and of different ages at three months intervals) and very heavy feeding, the annual net production has reached 8,000 kg per ha for ponds 2.5 to 3 m deep.

Most of the feeds used are similar to those already described but prepared in the following ways:

(i) Feeds of plant origin

Soybean milk: It is important for feeding all kinds of fish fry and is made by soaking soybean in clean water for six to ten hours, then grinding the bean with water through a stone mill (one part soaked bean to 12 parts water), filtering off the residue and using the milk while fresh by sprinkling or spraying it into nursery ponds.

Soybean cake: The residue left after oil has been pressed out of the beans is first broken into pieces, soaked in water and then broken into smaller pieces (for feeding omnivores), or ground into fine particles (for feeding plankton feeders). This is especially useful for feeding fingerlings.

Soybean residue: The residue obtained in the preparation of soybean milk and bean curd, is fed to both fingerlings and big fish.

Wolffia and small Lemna are used for feeding fingerlings of grass carp. They are sometimes specially cultured in fertile ponds or sections of canals for this purpose. Pistia, Eichhornia, and even Salvinia when chopped into small pieces are used for feeding grass carp and common carp. Alternanthera cooked and mixed with rice bran is well liked by all the major carps. Fresh rice stalks and leaves can be used for feeding grass carp of over one kg, smaller fish prefer finely chopped pieces; they also like pumpkin and potato stems and leaves.

(ii) Feeds of animal origin

Fresh-water snail and clams, such as Viviparus, Bullacta, Corbicula and Anadonta are excellent feeds for black carp. They are always used fresh and for feeding fingerlings they are broken into fine pieces. For feeding yearlings small ones are used whole but large ones are broken, while for big fish whole specimens are used.

3.4 Intensive feeding

Examples of intensive feeding may be illustrated by (i) the growing of carps in small running water ponds in Japan, (ii) the culturing of eels in Japan and Taiwan, (iii) the culturing of Pangasius catfish in pens in Thailand and Cambodia and (iv) the culturing of Clarias catfish in Thailand. In all these cases the ponds or pens serve only as holding space while the growth of fish depends entirely on the feeds given.

3.4.1 Rearing carps in small running-water ponds in Japan

This is a well known system of fish culture practised in Japan, and has been fully described in many publications. Ponds are always built along-side or close by streams with an ample supply of good running water the whole year round. The pond is small, about 30-100 m^2, and either rectangular or triangular in shape. The bottom of the pond is smooth but sloping and is usually cemented and paved with small rounded pebbles; the sides are constructed of stones. The inlet and outlet are designed to allow the efficient control of waterflow from the stream through the pond.

A pond of 50 m^2 and 1.8 m deep may be stocked with as many as 10,000 fingerlings of the common carp, each weighing about 75 g, and in one growing season (about seven months), a total harvest of about 8,200 kg of fish can be expected, a net gain of 7,500 kg of fish from about 30,000 kg of feeds used.

The fish are fed 12 to 18 times a day, from 0500 hours to as late as 2200 hours, depending on the temperature of water and size of fish. The warmer the water and the larger the fish the more frequently they are fed. Feeds are given during the period when the water temperature is from 16° to 30° C; below 16°C no feed is given.

The growing season is divided into three periods, (i) about 100 days, from beginning of May to beginning of August (fingerlings); (ii) about 40 days, from beginning of August to mid-September (young fish), and (iii) about 70 days, mid-September to end of November (big fish).

For growing, in a running water pond 50 m^2, 10,000 fingerlings (average weight 75 g, total weight 750 kg) through one growing season of about 210 days, to produce a harvest of about 8,200 kg fish or a net gain of 7,500 kg, the kinds and amounts of feed given are as follows:-

(i) first period (100 days)

wheat meal	500 kg
fresh silkworm pupae	6,100 kg
earthworms	10,000 kg

(ii) second period (40 days)

fresh silkworm pupae	7,000 kg

(iii) third period (70 days)

fresh silkworm pupae	7,000 kg

3.4.2 Eel (*Anguilla*) culture in Taiwan

Eel ponds range in size from 800 m^2 to 2,000 m^2, (1 to 1.5 m deep). The bottom of the pond consists of mud, is smooth and slightly sloping. The pond walls are cement lined brick or stone. Water inlets and outlets are well planned and constructed to maintain a continuous flow of water through the pond.

Eel fry of an average weight of 0.2 g are collected from lower reaches of rivers by special traps. They are cultured in nursery ponds to young eels, and then from young eels to marketable size in growing ponds.

The growth rate is rather slow. It takes about one year to grow from fry of about 0.2 g to young eels of about 20 g, and a second year from young eels to marketable size of about 200 g each.

The stocking rate for eel fry is about 300 specimens (total wt about 60 g) per m^2 and that for young eels is three or four (total wt about 60-75 g) per m^2.

Feed consists of trash fish, small crabs and other crustaceans unsuitable for human consumption, offal from slaughter houses, fish markets and fish processing plants, ox blood, earthworms, aquatic worms and silkworm pupae. The feed (except worms and pupae) is chopped into small pieces. Worms are used fresh. Dried silkworm pupae are soaked in fresh water for an hour or so before use.

Eel fry are fed mainly with worms and fine pieces of cooked trash fish. Silkworm pupae are used mostly in the last stage of rearing and fattening only. Feeding is done twice a day at fixed times and places. Feed is placed in feeding baskets (shallow bamboo baskets with large mesh) which are hung submerged along the edges of the feeding platform.

The daily ration of feed given varies from 5-10 percent of the estimated total body weight of eels present, according to temperature of water; more is given when water is warm. The conversion ratio varies from 10-15:1, depending on the quality of trash fish and the quantity of crustaceans present.

3.4.3 Catfish (*Pangasius* spp.) cultured in pens

This is a popular practice in Thailand and Cambodia. The pens are mostly made of bamboo splits or ratten and are set floating along river banks or the sides of the floating houses, and in shallow places resting on the bottom.

The pens are roughly of three sizes: (i) small - about 1 x 2 m by 1 m deep, used mainly for rearing fry, (ii) medium - 2 x 5 m by 1.5 m deep, (iii) large - 2.5 to 4.5 m x 7 to 10 m by 1.5 to 2 m deep.

The stocking rate is roughly 2,000 fry for each small pen; 1,000 fingerlings and young fish for medium pen; and 1,500 to 3,000 fingerlings and young fish for large pens

Principal feeds are trash fish, broken rice, rice bran, corn and tender aquatic plants. Trash fish are chopped into small pieces and are given either fresh or lightly cooked. Corn grains are used after partial cooking. Broken rice is cooked, is mixed with rice bran, chopped vegetables and small pieces of fish and made into small balls.

Fish are fed two or three times a day, either by throwing the feed into the pen through its door or by placing it in a feeding tray hung submerged inside the pen.

The amount of feed given daily ranges between four and six percent of the weight of fish, depending on the amount of material available. The conversion ratio has been estimated to be roughly 8-10:1.

An ingeneous method is commonly adopted for detecting any breakage of the pen. A definite number of Clarias, usually about five or six, are put into the pen together with the Pangasius. Each feeding time the number of Clarias is carefully counted. When the Clarias are all present, it means all is well, but when some of them are missing it indicates that the pen is broken somewhere and repairs are made promptly to prevent escape of Pangasius.

3.4.4 Catfish (Clarias spp.) culture in Thailand

This is an unique fish culture operation that involves extremely heavy stocking and intensive feeding. A small pond of 400 m^2 and 2.5 m deep can be stocked with as many as 40,000 fingerlings (total wt 600 kg), and by intensive feeding, at the end of a five months growing period, 4,300 kg of fish can be expected - a net gain of 3,700 kg of fish from about 26,000 kg of feed.

Pond areas range from 100 to 1,000 m^2, and depths from 1.5 to 3 m. The water is turbid and rather stagnant, but with provision for introducing fresh water into the pond whenever needed. A small water pipe is sometimes installed at the center of the pond to create a low fountain.

Both Clarias batrachus and C. macrocephalus are cultured, generally separately, but sometimes together. The fish are usually harvested at a weight of 200 g. Stocking rates per m^2 of water surface, and length of culture period from stocking to harvest, are as follows:

Size of fish stocked	No. per m^2 of water surface	Duration of culture in months
60 fish per kg	80-100	5 - 6
50 fish per kg	60- 80	4 - 5
40 fish per kg	40- 60	3 - 4

The principal kinds of feed used are fresh trash fish, small dogfish, and slaughter house, fish market and fish processing plant offal. When these are in short supply, cooked broken rice is used instead. The feed is chopped into small pieces (depending on size of fish to be fed), mixed and used as fresh as possible. Feed intended for use some hours later, or the next day, is cooked.

The fish are fed twice during the day and once at night. Feed is given slowly, handful by handful, from a wooden platform, until most of the fish stop feeding. The daily ration of feed given is roughly about 6 - 8 percent of the body weight of the fish. The conversion rate has been estimated to be about 6-8:1.

Similar heavy stocking and intensive feeding, with similar kinds and quantities of feed, are also being adopted in rearing Pangasius fry and fingerlings in small mud ponds (sometimes as small as 5 m x 10 m by 1 m deep).

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FEEDS AND FEEDING OF WARM-WATER FISH IN NORTH AMERICA

by

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Abstract

Research on the nutrition of warm-water fish in North America is still in its infancy. The first controlled experiments were not conducted until the early 1950s.

Currently there are four research stations in the United States actively engaged in research on the nutrition of warm-water fish: The Agricultural Experiment Station, Auburn University, Auburn, Alabama; the South-eastern Fish Cultural Laboratory, U.S. Fish and Wildlife Service, Marion, Alabama; the Fish Farming Experimental Station, U.S. Fish and Wildlife Service, Stuttgart, Arkansas; and Kansas State University, Manhattan, Kansas.

Almost all of the research work on the nutrition of warm-water fish has been concerned with the channel catfish (*Ictalurus punctatus*). Using this species, research has been carried out on nutrient requirements (protein, carbohydrate, fat, vitamins, calories and bulk); formulation of practical diets and factors affecting the feeding of this species.

The review also includes information on the nutrition of other species where appropriate.

ALIMENTS ET ALIMENTATION DES POISSONS D'EAU CHAUDE EN AMERIQUE DU NORD

Résumé

En Amérique du Nord, la recherche sur l'alimentation des poissons d'eau chaude n'en est encore qu'à ses débuts, les premières expériences contrôlées n'ayant eu lieu qu'au début des années 50.

Aux Etats-Unis d'Amérique, quatre stations de recherche s'occupent activement de recherche sur l'alimentation des poissons d'eau chaude: la Station d'expérimentation agricole de l'Auburn University, Auburn (Alabama), le Laboratoire de pisciculture de la région sud-est de l'U.S. Fish and Wildlife Service, Marion (Alabama), la Station expérimentale de pisciculture de l'U.S. Fish and Wildlife Service, Stuttgart (Arkansas), et la Kansas State University, Manhattan (Kansas).

La quasi totalité des travaux sur l'alimentation des poissons d'eau chaude a porté sur le "channel catfish" (Ictalurus punctatus). Ce poisson-chat a fait l'objet de recherches sur les besoins en éléments nutritifs (protéines, hydrates de carbone, matières grasses, vitamines, calories et ballast), sur l'élaboration de régimes alimentaires pratiques, et sur les facteurs intervenant dans l'alimentation de cette espèce.

La communication fournit également certains renseignements sur l'alimentation d'autres espèces.

LOS ALIMENTOS Y LA ALIMENTACION DE LOS PECES DE AGUAS TEMPLADAS EN AMERICA DEL NORTE

Extracto

Las investigaciones sobre la alimentación de los peces de aguas templadas en América del Norte se hallan todavía en su infancia. Los primeros experimentos controlados sólo se realizaron a primeros de la década de 1950.

Actualmente en los Estados Unidos existen cuatro estaciones de investigación que se ocupan activamente de la nutrición de los peces de aguas templadas: La Estación Agrícola Experimental, Universidad de Auburn, Auburn, Alabama; el Laboratorio Piscícola Sudoriental, Servicio de Pesca y Fauna Silvestre de los Estados Unidos, Marion, Alabama; la Estación Experimental de Piscicultura, Servicio de Pesca y Fauna Silvestre de los Estados Unidos, Stuttgart, Arkansas; y la Universidad del Estado de Kansas, Manhattan, Kansas.

Casi toda la labor de investigación sobre la alimentación de los peces de aguas templadas se ha ocupado del bagre de canal (Ictalurus punctatus). Con esta especie se han realizado investigaciones sobre las necesidades de nutrientes (proteinas, carbohidratos, vitaminas, grasas, calorías); la preparación de raciones práticas y los factores que influyen en la alimentación de esta especie.

El estudio incluye también información sobre la alimentación de otras especies, cuando es aconsejable.

III/R-3

1 INTRODUCTION

Research on the nutrition of warm-water fishes is still in its infancy. The first controlled experiments were not conducted until the early 1950s and most of the critical information on the subject has been obtained since 1960. When compared to the wealth of information available on trout nutrition there is still much to be learnt in the field of warm-water fish nutrition.

Research or experimentation on the feeds and feeding of warm-water fish had a novel beginning in the United States. Unlike most countries where experimentation on feeds and feeding of warm-water fish was initiated because of the need to increase the production of fish in ponds for food, in the United States the earliest experimentation was carried out by individuals engaged in rearing minnows for sale to sport fishermen. As early as 1946, several years before the first formal experimentation on nutrition of warm-water fish, producers of goldfish (Carassius auratus) in the South were utilizing diets composed of complex mixtures of animal and vegetable products. Results of informal experimentation by minnow producers did not contribute directly to advancing knowledge on the nutrition of warm-water fish. The feed mixtures used by various producers were often secret formulas and as such the exact composition was a closely guarded secret. Probably the most significant contribution of these experiments was the demonstration that the production of warm-water fish in static waters could be increased significantly by feeding.

The number of research stations engaged in research on warm-water fish nutrition is rather small. When the experiments are adequately designed and replicated a large number of expensive ponds with similar construction features is required. This has probably limited the number of organizations engaged in research on warm-water fish nutrition. Currently there are four research stations in the United States actively engaged in research on warm-water fish nutrition: Agricultural Experiment Station of Auburn University, Auburn, Alabama; the South-eastern Fish Cultural Laboratory, U.S. Fish and Wildlife Service, Marion, Alabama; the Fish Farming Experimental Station, U.S. Fish and Wildlife Service, Stuttgart, Arkansas; and Kansas State University, Manhattan, Kansas. A number of other organizations are developing facilities for such work, but are not actively engaged in research at this time.

Current research on the nutrition of warm-water fish in the United States is being approached from two slightly different directions depending to some extent on the station conducting the research. For example, at the South-eastern Fish Cultural Laboratory the emphasis is primarily on determining the nutrient requirements of warm-water fish utilizing purified diets and in most cases purified ingredients. In this work the experimental fish are maintained in troughs without access to natural foods. A second approach, one being followed at the Fish Farming Experimental Station, involves the testing of diets formulated from various combinations of ingredients normally utilized in animal feeds. These diets are tested under actual pond conditions. Both approaches yield valuable information.

Almost all of the research completed to the present time on the nutrition of warm-water fishes involves the channel catfish (Ictalurus punctatus). Very little work has been carried out on other species. Although there are a relatively large number of warm-water fishes in North America that will respond to supplemental feeding, the channel catfish is currently the only species that will command a high enough market price to justify the expense. Consequently, this paper will be confined essentially to the summarization of the research on the feed and feeding of the channel catfish, with reference to other species whenever appropriate.

2 NUTRIENT REQUIREMENTS OF WARM-WATER FISH

There is little information on the comparative nutrition of warm-water and cold-water fishes. Since the separation of the two groups is an artificial one, there are probably more differences in nutritional requirements between species within one of the artificial groups than between the two groups of fishes; however, since cold-water fish evolved in an environment that was never warmer than 15°-17°C, there may be significant differences in the metabolic dynamics of the two groups of fishes which require different amounts of certain nutrients.

2.1 Proteins

A few studies have been completed on the protein requirement of warm-water fish. Most of these have involved the channel catfish. The earlier experiments measured the growth response to purified diets containing various levels of purified proteins such as casein, soybean protein, and gluten. Nail (1962) using the channel catfish in experiments in steel troughs demonstrated that the relationship between percentage gain in weight and percentage of protein (casein) in the diet was linear at dietary protein levels from 6.3 to 25.3 percent, but not when the protein level was increased to 34.8 percent. Although there was an increase in growth rate when protein was increased from 25.3 to 34.8 percent the conversion of feed protein into fish protein decreased relative to the conversion rates obtained at the lower levels of protein. Work at the South-eastern Fish Cultural Laboratory (Anon., 1962) demonstrated that the relationship between growth and percentage of protein in the diet was linear up to 39.1 percent protein, but not to 50.2 percent protein. The results of the two studies reported above indicate that the amount of protein in the form of casein required by channel catfish is between 25 and 39 percent. Apparently the divergence in the estimates of the optimum amount of protein by the two studies is a result of differences in experimental procedure. Recently workers at the South-eastern Fish Cultural Laboratory (Unpublished) recommended that diets for channel catfish should contain 28 percent protein. Hastings (1964b) noted that test diets used in ponds at the Fish Farming Experimental Station are formulated with not less than 32 percent protein. The feed used in experiments on commercial fish production and supplemental feeding for sport fish at the Auburn University Agricultural Experiment Station contains 46 percent protein (Prather, 1958).

A number of studies have shown that the amount of protein required for optimum growth is dependent on the quality of the protein. Research at the Fish Farming Experimental Station (Anon., 1964) demonstrated that fish meal was a better source of protein for channel catfish than was casein, soybean meal or feather meal. Using casein as the standard, the following results were obtained:

Protein source	Performance (percent)
Casein	100
Fish Meal	120
Soybean meal	49
Feather meal	43

Work at the South-eastern Fish Cultural Laboratory (Anon., 1962) indicated that casein was superior to either soybean protein or gluten in promoting growth in channel catfish. There was little difference between gluten or soybean protein. Krisnandhi and Shell (1965) also reported data demonstrating the superiority of casein over purified soybean protein. The degree of superiority was dependent on the amount of protein in the diet. Some of these data are shown in the following table:

Level of protein in diet (percentage)	Percentage gain in weight on:	
	Soybean protein	Casein
5	6.1	22.7
30	86.1	110.6

Also included in this study was an evaluation of a combination (1:1) of casein and soybean protein. The combination protein produced similar growth to casein alone when fed in diets containing 5 percent protein, but produced better growth than casein alone at a 30 percent level.

Research conducted at Auburn (Unpublished) indicates that both the amount of protein and the amount of carbohydrate in the diet of channel catfish affects the amount of protein extracted from the feed. Some of these data are shown in the following table:

Level of protein in diet (percentage)	Percentage of protein in faeces (dry) of fish receiving diets containing:	
	9.3 percent carbohydrate	18.6 percent carbohydrate
6.3	0.90	1.31
15.8	0.77	1.11
25.3	1.63	1.57
34.8	2.51	3.27

Very little research has been conducted on the amino acid requirements of warm-water fish. The South-eastern Fish Cultural Laboratory has initiated some research in this area by feeding channel catfish purified diets containing the amino acids required by chinook salmon (Oncorhynchus tshawyscha) (Anon., 1962; Anon., 1963). The channel catfish receiving this diet failed to gain weight. In subsequent trials using different diet binders, mineral mixtures, levels of bulk, type and level of carbohydrate, etc., the experimental fish were still unable to grow on that particular sequence of amino acids.

2.2 Carbohydrates

There has been little work on the carbohydrate requirements of warm-water fish. Nail (1962) determined the effect on growth of two levels (9.3 and 18.6 percent) of carbohydrate fed in purified diets to channel catfish. This research demonstrated that the higher level of glucose significantly increased the rate of growth. On the basis of this study Nail also concluded that 1 g of carbohydrate spared 0.22 g of protein (casein) in his experiments. Tiemeier, et al. (1965) working with channel catfish noted a sparing action of carbohydrate on protein when fish were fed diets containing 25 percent protein but not when fish were fed diets containing 35 percent protein. Dupree at the South-eastern Fish Cultural Laboratory determined the efficiency of different carbohydrates in promoting growth in channel catfish (Anon., 1965). He concluded from an experiment in which he incorporated glucose, maltose, dextrin and starch into purified diets at levels of 7.5, 15.0 and 30.0 percent that better growth was obtained on diets containing the larger carbohydrate molecules (starch and dextrin). Weight gain increased with increased starch and dextrin in the diets. There was no increase in growth regardless of the amount of glucose or maltose in the diets.

Dupree and Sneed (Unpublished), on the basis of their work at the South-eastern Fish Cultural Laboratory, recommend 20 percent carbohydrate as the most efficient level for channel catfish; however they noted that acceptable growth can be obtained on carbohydrate levels from 10 to 20 percent.

2.3 Fats

Less attention has been given to the fat requirement of warm-water fish than to any other major class of nutrient. At the South-eastern Fish Cultural Laboratory (Anon., 1965) channel catfish were fed diets containing liquid corn oil, partially hydrogenated corn oil and beef tallow at rates of 3,7 or 15 percent of the weight of the dry diet. Best growth was obtained on diets containing 7 percent corn oil. Growth was reduced in the fish receiving diets containing 15 percent corn oil. Results with hydrogenated corn oil were similar to those obtained with liquid corn oil. Growth of fish receiving beef tallow as the source of fat decreased as the level of tallow in the diet was increased.

2.4 Vitamins

One of the earliest papers reporting research results on the nutrition of warm-water fish involved the vitamin requirement of channel catfish and goldfish. Jewell, et al. (1933) utilizing synthetic diets demonstrated that channel catfish required vitamin D in their diet. They further noted that the inclusion of fresh meat in a theoretically adequate diet resulted in a 13 percent increase in the growth of channel catfish. Zabari (1956) produced avitaminosis in common carp held in troughs by feeding a diet of peanut meal and fish meal. Symptoms disappeared in the affected fish when injected either with a mixture of pyridoxine, calcium pantothenate and folic acid or a mixture of riboflavine, B-12, and choline. An injection of thiamine alone did not alleviate the condition.

Dupree (1960) demonstrated a need in channel catfish for pyridoxine, pantothenic acid, riboflavin, thiamine, folic acid, nicotinic acid, B-12, choline, vitamin A and vitamin K. No requirement was shown for biotin, inositol, ascorbic acid or para-amino-benzoic acid.

The question often arises on the desirability of including vitamins in practical diets where fish will be able to eat natural foods. Work at the Fish Farming Experimental Station has shown that a vitamin premix added to practical diets resulted in better growth of catfish fingerlings than where experimental fish were receiving a diet not including the vitamin premix (Anon., 1964). There is little doubt that at low stock densities natural foods will provide adequate vitamin nutrition; however as the density of the stock increases, natural foods play a decreasing role in supplying the necessary vitamins. Apparently the limiting point of fish production imposed by the total amount of a given vitamin available to fish in a pond is somewhat below the limiting point imposed by physical limitation of the environment such as the ability of the environment to provide the fish with adequate oxygen. This fact has been demonstrated by research at Auburn (Unpublished). Apparent avitaminosis developed among goldfish due to their being held in an extremely crowded condition in ponds. The chemical and physical characteristics of the ponds could not be implicated in any of the deaths of fish resulting from this condition.

2.5 Calories

Phillips, et al. (1964) demonstrated that by proper attention to the caloric content of the diet of trout (Salmo spp.) growth could be maintained on protein levels below levels usually required for maximum growth, but little effort has been expended on the effect of varying the calorie intake of warm-water fish. Hastings (1964) contributed some information on the calorie balance in diets of channel catfish. He recommended that total calories be more than 2,964 per kg of diet and that calories derived from protein be more than 1,334 per kg. Tiemeier, et al. (1964; 1965; 1966) have included studies on calorie intake in their experiments on channel catfish nutrition, but have not made a recommendation on the optimum calorie intake for this species.

2.6 Minerals

There has been almost no research conducted on the mineral requirements of warm-water fish. A research worker at Florida State University, Tallahassee, Florida reported (personal correspondence) that iron included in the diet of fish significantly increased the growth rate of experimental fish. There have been no published reports on this subject.

2.7 Bulk in the diet

The effect of non-nutritive bulk in the diet on the growth of channel catfish has been determined at the South-eastern Fish Cultural Laboratory (Anon., 1963). Experimental fish were fed diets containing 0, 10, 20, 40 and 50 percent bulk in the form of alphacellulose flour. The total nutrient content in the diets was equal. Best growth was obtained on diets containing 10 percent bulk. There was no difference in the growth obtained on diets containing 0, 20, 40, and 50 percent bulk. Test diets for channel catfish in use at the Fish Farming Experimental Station includes less than 20 percent fibre (Hastings, 1964).

2.8 Use of additives in diets

In some cases materials are added to the diet of warm-water fish for specific purposes other than that of meeting the basic nutritional requirements of the fish. Sulphamerazine has been included in practical diets fed to goldfish in ponds at Auburn (Unpublished) to combat bacterial gill disease. There was no mortality associated with feeding this drug at rates from 0.05 to 1.0 percent of the dry weight of the feed. Allison (1957) noted that di-n-butyl tin oxide included in the diet of channel catfish controlled the fish tapeworm Corollobothrium sp. and the intestinal fluke Alloglossidium sp. when administered at a rate so that the fish received approximately 250 mg of the chemical per kg of body weight.

Hastings at the Fish Farming Experimental Station included fungal and bacterial amylases in pelleted feeds (Anon., 1965). He reported that these enzymes failed to promote increased growth or feed conversion even though care was taken to prevent the inactivation of the enzymes during feed processing and storage.

Experiments have been conducted at the South-eastern Fish Cultural Experiment Station to determine the effect of various sex hormones and hormone-like substances on ovarian and testicular development (Anon., 1963). Enovoid fed to goldfish caused significantly reduced ovarian weight, norlutin produced a slightly less inhibitory effect. Delalutin and Provera caused significant increases in ovarian weight. Delalutin also caused a significant increase in the testicular weight of goldfish. No mortality resulted from feeding these materials.

3 FEEDS FOR WARM-WATER FISH

In the previous section results of research on the nutrient requirements of warm-water fish were summarized. In this section results of research to develop practical diets to meet those requirements for nutrients will be reviewed.

3.1 Diet formulations

As has previously been noted, experimentation on feeds for warm-water fish was carried out on a rather informal basis in the late 1930s and early 1940s by private hatcherymen interested in growing minnows for the live bait market. The feeds used for this purpose appear to be very similar to meal mixtures utilized in trout nutrition during that period. Swingle at Auburn (Unpublished) was adding vegetable meals to ponds as early as 1937, but this material was added as an organic fertilizer. Swingle (Unpublished) began informal experimentation of feeding of fish in small ponds in 1941. In these experiments he noted that excessive feeding of bread to goldfish resulted in decay of the uneaten feed and death of the fish - one of the limiting factors of warm-water fish production in static water. In 1943 he began to experiment with the feeding of the bluegill (Lepomis macrochirus). He noted that 3.6 kg of bread were required for each kg of gain in weight.

Fish husbandrymen at the U.S. Fish-Cultural Station, Neosho, Missouri were feeding channel catfish the following prepared diet in 1947 (Anon., 1947):

Ingredient	Percentage in diet
Crayfish abdomens	50.0
Fish meal	16.6
Cottonseed meal	16.6
Dried skim milk	16.6

This diet apparently was not developed experimentally but rather seems to have been an attempt to emulate the meal-meat mixture successfully used in trout hatcheries at that time.

Swingle at Auburn in 1947 (Unpublished) was principally interested in production of fish in ponds for fishing, and in that year he began to make use of another form of feed for feeding bluegill in ponds containing largemouth bass (Micropterous salmoides) and bluegill. He fed commercial turkey and poultry laying mash (pelleted), and concluded that production of bluegill was increased approximately 448 kg/ha over production that could be obtained with fertilization alone. The promising results obtained in the 1947 experiments led Swingle and Prather (Unpublished) to begin experimenting with various animal and plant products as possible feeds for the bluegill. In that year they tested grain sorghum, cracked corn, cottonseed cake, a commercial trout feed, white wheat bread, hog supplement, laying mash (pelleted form), wheat and a mixed feed consisting of 35 percent cottonseed meal, 35 percent soybean meal, and 30 percent dry skim milk. Only the mixed feed, the laying mash and the cottonseed cake produced promising results. The mixed feed produced the best results but 3.4 kg were required for 1 kg of gain.

As a result of contacts with minnow growers and their interest in the development of better diets, Prather (Unpublished) began in 1948 at Auburn a series of experiments on feeds for goldfish and fatheads (Pimphales promelas). He utilized poultry laying mash and the mixed feed used by Swingle for bluegill in that year (35 percent cottonseed meal, 35 percent soybean meal and 30 percent dry skim milk) in his experiments. In 1949 the combination feed was abandoned for single ingredient diets: cottonseed meal, wheat shorts, red dog flour, laying mash, soybean meal and a 1:1 mixture of hog supplement and soybean meal.

The first experiments on the feeding of warm-water food fish was initiated at Auburn by Swingle in 1949 when he fed whole white corn, whole wheat, grain sorghum or hog supplement to common carp (Cyprinus carpio) in small ponds. This work was followed in 1949 by feeding speckled bullheads (Ictalurus nebulosus) poultry laying mash, and in 1950 by feeding channel catfish soybean meal.

In 1950, after several years of experimentation with various feed ingredients, soybean meal and cake were apparently chosen as the standard feeds for growing warm-water fish at the Auburn Station; however, beginning in 1953 and continuing into 1954, goldfish held in ponds under extremely crowded conditions and fed on soybean cake alone died in large numbers. All of the dead and dying fish displayed a very characteristic erosion of tissue and cartilage around the mouth and head. In 1954 when the symptoms first appeared, the soybean cake was replaced with fish meal. Following the change in diet the mortality rate decreased significantly.

Following the demonstration in 1954 that soybean meal cake was not nutritionally balanced enough to be used as a supplemental feed, Prather (1957) formulated the first of the so-called Auburn fish feeds (Auburn No.1) composed of:

Ingredients	Percentage in diet
Soybean meal	35
Peanut meal	35
Fish meal	15
Distiller's dry solubles	15

Also beginning in 1954 some tests were conducted using a mixture of peanut meal or soybean meal and fish meal (6:1); however, as Swingle (1957) pointed out even this mixture proved to be inadequate as stocking rates and the resulting production were increased. Zobari (1955) tested a peanut meal-soybean meal-fish meal combination as a feed for common carp under laboratory conditions in which the fish did not have access to natural food. This mixture caused avitaminosis in the carp.

By the late 1950s considerable interest had been generated in the possibilities of high production of fish, especially channel catfish, in ponds by the use of supplemental feeding. Swingle's paper (1954) on commercial fish production in ponds no doubt generated a great deal of this interest. This interest immediately led to a concern over the type of feed required for adequate nutrition. Nelson (1957) suggested that feeding of channel catfish fry was a very important part of the culture of the species. He further suggested that the feed should be high in protein, preferably of animal origin. There was also renewed interest in the dry meal diets used to feed trout. A diet of this type was formulated and utilized by fish culturists growing channel catfish at a state-operated fish hatchery in Arkansas (Crawford, 1957). The diet consisted of the following ingredients:

Ingredient	Percentage in diet
Dried milk	25.75
Wheat shorts	7.00
Soybean meal	7.00
Meat scraps	30.00
Fish meal	28.00
Vitamin-A feeding oil	0.25
Iodized salt	1.00
Brewer's dried yeast	1.00

Crawford also reported what was probably the first concern for the nutritional requirements of brood fish. He noted that the brood fish were fed a diet of fresh, cut fish. He also reported the use of an atibiotic (terramycin) as an additive to the feed when young fish appeared to be sick.

In 1958 the Auburn No.2 fish feed was formulated (Prather, 1958). This new formulation was essentially the same as the Auburn No.1 except that ground peanut cake was substituted for the peanut oil meal. The Auburn fish feeds were formulated as supplemental feeds or feeds designed to supplement the natural food supply in ponds. Beginning in 1962 some experiments were conducted in troughs by Shell (Unpublished) at Auburn to determine the value of Auburn No.2 as a complete diet for channel catfish. These experiments were designed to compare the growth response of two commercial pelleted hog feeds, a commercial supplemental fish feed, and Auburn No.2. The fish on the two hog feeds grew well for a short period but then began to die in large numbers. The suspected cause was the relatively high level of antibiotics in the hog feeds. Fish being fed on the commercial supplemental fish feed grew significantly faster and converted feed into fish at a much better rate than fish receiving Auburn No.2. The commercial product although designed to sell as a supplemental product was a more complex formulation than Auburn No.2 and seemed to be much better balanced nutritionally; however, it was later shown in an extended experiment that the commercial product was not adequate, and performed very poorly in tests in comparison with a "complete" trout ration.

Beginning in 1963 Hastings (Anon., 1963) and his co-workers at the Fish Farming Experimental Station began their first experiments to place nutrition of channel catfish and other warm-water fish on the same sound basis as poultry and livestock nutrition. In that year he began to experiment with the use of combinations of animal and vegetable products mixed in varying proportions. The ingredients included rice bran, yellow corn meal, wheat shorts, dried whey, soybean meal, cottonseed meal, distiller's solubles, poultry by-products, fish meal, and peanut oil meal. He compared the results of the feeding experiments on the basis of rate of conversion, cost of feed per pound of gain, and weight gain per acre. Hastings concluded that several combinations of vegetable and animal products produced above average gain on less than average cost. He further noted that rations containing fish meal produced better growth than those without this ingredient. On the basis of these studies Hastings (1964) recommended the following formulation (slightly modified for ease in presentation in tabular form) for feeding channel catfish:

Ingredient	Percentage in diet
Grain by-products	45.0
Fish meal	10.0
Protein concentrate of animal origin (other than fish meal)	12.5
Protein concentrate of plant origin	22.5
Dehydrated alfalfa	4.0
Distiller's solubles	5.0
Mineralized salt	1.0

These specifications were designed to provide the following percentages of each nutrient class:

Nutrient	Percentage in the diet
Protein	32
Fat	More than 4
Fibre	Less than 20
Total calories	More than 2964 per kg
(protein calories)	(more than 1334 per kg)
Calcium	More than 1 percent
Phosphorus	More than 1 percent

Hastings further concluded that vitamin and mineral additives other than those included in the distiller's solubles and the mineralized salt are justified only if the feed is to be used as a starting ration for young fish or if the feed is to be used in raceway culture.

By specifying percentages of plant and animal products rather than percentages of specific ingredients, Hastings' approach to feeds for warm-water fish has the advantage that feeds can be formulated using the most readily available materials in any area of the country. This also allows feed processors to alter the diet as prices of ingredients change seasonally or from year to year without changing the nutritional value of the feed.

Tiemeier and his co-workers at Kansas State University have also conducted research on the use of various vegetable and animal products in diets for channel catfish (Tiemeier, et al., 1965). Utilizing soybean oil meal, dehydrated alfalfa meal, ground grain sorghum, wheat shorts, wheat meal, wheat bran, vegetable fat, fish meal, meat and bone meal, blood meal, distiller's dried soluble, and sesame oil meal, several diets were formulated. Feeding trials were evaluated on the basis of weight gained, conversion rate, and cost per pound of fish. When considering all of these factors there was no difference in the diets. It is interesting that this work demonstrated little value in varying the amount of fish meal; diets containing from 0.5 to 8.8 percent fish meal all produced similar results. Hastings (1964) suggested that diets for channel catfish should contain not less than 10 percent fish meal. On the basis of Tiemeier's work the following formulation was recommended (Hartley, 1966):

Ingredient	Percentage in diet
Fish meal	5.00
Soybean meal	30.00
Meat scraps	20.00
Dried buttermilk	5.00
Wheat middlings	18.00
Dehydrated alfalfa meal	15.00
Distiller's solubles	5.00
Salt	1.75
Antibiotic	0.25

In preliminary tests at Auburn the peanut cake in Auburn No.2 fish feed has been replaced with cottonseed meal. This new formulation (Auburn No.3) has been tested on channel catfish. In tests conducted in concrete pools and in earthen ponds growth on both diets was essentially the same.

Natural foods play an important role in the nutrition of warm-water fish grown in ponds. Work at Auburn (Unpublished) indicates that a much larger amount of natural food is produced in ponds receiving supplemental feeding than in ponds receiving only fertilization. Work with channel catfish at the South-eastern Fish Cultural Laboratory (Dupree and Sneed, Unpublished) indicated that natural foods were adequate to supplement nutritionally incomplete diets until the weight of fish in the pond exceeded approximately 1568 kg/ha and that the limit may be somewhat higher than this.

Rogers (1963) has conducted some experiments on the use of artificial cover or attachment surface to increase the production of aquatic diptera in ponds. Lewis, et al. (1963) conducted experiments on the suitability of several types of animal forage as food for channel catfish in ponds. They concluded that crayfish or other invertebrates are the only animal forage reasonably vulnerable to the channel catfish.

Very little work has been done in North America on the use of fresh vegetable forage as food for warm-water fish. Tongsanga (1963) conducted some tests on the use of the leaves of kudzu (Pueraria thunbergiana) by three species of tilapia. His data indicated that feeding the green leaves resulted in better growth than when fish were maintained in ponds receiving only inorganic fertilizer.

3.2 Feed processing

In early experiments on the nutrition of warm-water fish the test diets were usually presented to the fish as a dry meal mixture. Beginning in the later 1950s studies were initiated on the value of pelleting the diets. By that time pelleting equipment for processing various pelleted livestock feeds was in widespread use. Also about this time several feed processors were beginning to pellet diets for trout.

Experiments comparing Auburn No.1 fish feed presented as pellets or as a meal were initiated at Auburn in 1957. These experiments indicated that when this diet was pelleted, 23 percent less feed was required to produce a kg of carp (Cyprinus carpio, Israeli strain of the mirror carp) than when the diet was presented as a meal. With the channel catfish the effect of pelleting was even more striking (Swingle, 1958). In this experiment ponds were stocked with the same number of fish and received the same amount of feed. The following results were obtained:

Feed	Fish produced (kg/ha)	Feed conversion
Auburn No.1 (meal)	1400	3.3
Auburn No.1 (pellets)	2646	1.6

Prather (1958) conducted experiments on the comparative value of three forms of the Auburn No.1 diet (meal, crumbles, and 3/8-inch (9.5 mm) pellets) as a feed for fathead minnows. He obtained the following results from groups of ponds stocked alike and receiving similar amounts of feed:

Feed	Gain in weight (kg/ha)
Meal	147
Crumbles	164
Pellets	188

Even though a 3/8-inch (9.5 mm) pellet was much too large for the fathead, presentation of the diet in this compact form resulted in more efficient utilization of the feed.

Hastings (1964) contributed valuable information of methods of improving the stability of pellets in water. He tested the stability of various pellets by placing a pre-weighed amount of dry pellet on a piece of aluminium screen and immersing it. After ten minutes the pellet was recovered, dried and the loss in weight determined. Using this system of evaluation it was determined at the Fish Farming Experimental Station that grinding of feeds before pelleting increases stability (Anon., 1964). Also stability was increased by adding organic flours (soy flour, dried wood pulp liquor, and rice mill dust (sifted through No.80 sieve)). In later research it was demonstrated by Hastings that gelatinized corn solids, guar meal and bentonite did not improve pellet stability (Anon., 1965).

Factors in the processing of feed other than form (meal vs. pellet) are of importance in the nutrition of warm-water fish. Hastings (1963) has warned that processing of the ingredients into a finished product may destroy or reduce the concentration of important nutrients such as vitamins and enzymes without affecting the protein, fat, and carbohydrate composition of the mixture. He further suggested that digestibility might also be affected.

4 FEEDING OF WARM-WATER FISH

Correct nutrition of warm-water fish involves not only developing a suitable feed but also involves the feeding procedure itself. The best diet possible will give poor results unless such factors as the amount of the diet required by the fish, the effect of temperature on feeding activity, the frequency of feeding, etc. are considered. The information available on the mechanics of feeding will be summarized here.

4.1 Amount of feed required

One of the fundamental problems in the feeding of fish is the amount of feed required. If too little feed is provided most of it will be required for maintenance leaving little for growth; consequently the conversion of feed into fish will be very poor. If the amount of feed provided is too great, the fish will not be able to consume the entire amount. This will result in wasted feed and also poor conversion. Wasted feed may also lead to other problems when oxidation and mineralization of the organic matter in the feed takes place in the water. Lowering of the water quality because of the pollution may lead to more inefficient utilization of feed. Shell at Auburn (Unpublished) has shown that when conversion rates are plotted against their respective feeding rates (percentage of body weight) parabolic-shaped curves are produced for both the channel catfish and *Tilapia mossambica*.

The total amount of food required increases as the size of the fish increases, but the percentage required decreases. Trout nutritionists are able to utilize this type of information to make very exact adjustments in the amount of feed given to various sizes of fish (Phillips, *et al.*, 1963). The relationship between size of fish and amount of feed required must also hold for warm-water fish although there has been little effort to obtain quantitative information of this type. Probably this degree of refinement in determining the amount of feed required will not be needed so long as warm-water fish culture is confined to ponds; however, if attempts are made to culture warm-water species such as the channel catfish in raceways this degree of refinement may be necessary. The amount of natural food available in ponds probably compensates for slight errors in feeding rates for small fish in ponds, and in older fish the feeding rate probably changes very little; however, in raceways where there is little or no natural food the amount of feed required for most efficient utilization will be more critical.

Swingle (1958) proposed a sliding scale feeding system for channel catfish in which the feeding rate decreased as the weight of fish in the pond increased

Estimated weight (kg) of fish per ha	Weight (kg) of pelleted Auburn No.2 feed fed per ha per day	Feeding rate (percentage of body weight)
11-34	1.1	3-10
56	3.4	6
112	5.6	5
224	11.2	5
336	13.4	4
448	17.9	4
560	22.4	4
784	28.0	3.8
896	33.6	3.8
1008	33.6	3.3
1344	33.6	2.5

The system was developed from field observations of the feeding of channel catfish. This system does not take fish into consideration directly; however, it was intended to apply to ponds in which channel catfish were stocked as fingerlings.

Swingle (1967) has provided further information on the rates of feeding for efficient utilization of feed by different sizes of channel catfish and white catfish (Ictalurus catus). The following data were obtained by feeding Auburn No.2 fish feed when water temperatures were above 16°C:

Average total length (cm)	Daily rate of feeding (percent)
2.4 - 12.0	5.0
12.0 - 15.6	4.0
15.6 - 24.0	3.0
24.0 - 28.5	2.5
31.2 -	1.5

The same type of information was also provided by Swingle (1966) for three species of Tilapia, T. mossambica, T. melanopleura and T. nilotica (= aurea). The following data were obtained in experiments using Auburn No.2 fish feed; water temperature remained above 22°C during the experimental period:

Average total length (cm)	Daily rate of feeding (percent)
2.4 - 12.0	5
12.0 - 24.0	3

Since so little information is available on the effect of fish size on the amount of feed required, channel catfish culturists simply increase the amount of feed added to the ponds as the size of fish and the weight of fish in the ponds increase. The actual feeding rate in percentage of body weight remains approximately constant throughout the growing period although feeding rates may be somewhat higher than 3 percent when ponds are stocked.

4.2 Feeding at low water temperature

Also of fundamental importance in the feeding of warm-water fish is the effect of water temperature on feed consumption. The effect of temperature is of equal importance with the effect of fish size on feed requirement. There has been little effort to determine the exact effect of temperature on the feed requirement of warm-water fish.

Swingle (1954) conducted experiments to determine the months during which feeding would be beneficial for the speckled bullhead Ictalurus nebulosus marmoratus. From these tests it appeared that the speckled bullhead did not utilize food when the water temperatures dropped below 16°C.

Several workers have noted that feeding of channel catfish is not practical when water temperature is low. Swingle (1958) noted that channel catfish were fed only when water temperature exceeded 16°C; however, he suggested that feeding of brood fish be continued until the water temperature went below 10°C. He also suggested that fingerlings be fed at a rate of 1 percent of body weight daily until the water became colder than 7°C. Prather (Unpublished) at Auburn has demonstrated that fingerling channel catfish will respond to supplemental feeding in the winter, but that approximately five times as much feed is required per unit of gain than is required during the summer.

Swingle and Shell (Unpublished) in experiments to determine a suitable feeding rate for channel and white catfish during the winter months found that food conversion was very poor in both species in the period November to March when fed at rates of 3 or 4 percent. Conversions were significantly improved in ponds where fish were fed 1 or 2 percent rates during the same period. Tiemeier et al. (1964) noted that in Kansas it is recommended that feeding should not be continued when water temperature drops below 18°C.

The feeding of channel catfish is generally suspended when the water temperature falls below 15.6-18.3°C, but Hartley (1966) suggests a reduction beginning in mid-September until only approximately one-half the maximum amount fed in summer is being fed by mid-October.

4.3 Determination of the amount of feed

Determination of the amount of feed to place in ponds containing warm-water fish is also a problem. In trout culture the fish are usually readily seen and adequate samples on which to base weight estimates are easy to obtain. In warm-water fish culture in ponds this is generally not possible. The fish are seldom visible and representative samples are difficult to obtain. Most catfish farmers simply rely on feeding schedules provided by research and extension organizations. These recommendations are based on specific stocking rates, average mortality rates and growth rates of channel catfish in a particular state. Hartley (1966) has prepared the following feeding schedule for growing channel catfish to marketable size in Kansas. The feeding schedule assumes a stocking rate of 2,470 fingerlings per ha.

Period	Kg/ha of feed given daily
April 15-30	0.9
May 1-15	1.6
May 16-31	2.5
June 1-15	4.7
June 16-30	6.3
July 1-15	8.1
July 16-31	9.4
August 1-15	11.2
August 16-31	14.4
September 1-15	14.4
September 16-30	9.4
October 1-15	6.3

Prather (1964) also proposed a general daily feeding schedule for pond owners growing channel catfish for use as sport fish. His feeding rate is based on stocking 7,410 fish per ha in winter using Auburn No.1 fish feed. The recommended feeding schedule is as follows:

Month	Kg/ha/day
March	3.4
April	5.6
May	11.2
June	14.6
July	18.0
August	22.4
September	28.0
October	33.6

Tiemeier, et al. (1964) recommended that feeding rates be adjusted at two-week intervals for channel catfish and that the amount of feed should be based on 4 percent of body weight per day. In this case samples for weight estimates must be obtained at bi-weekly intervals.

Swingle (1967) has proposed an entirely different approach to estimating the weight of warm-water fish in ponds for determining the amount to feed. His method is based on determination of the expected conversion rate for a given species, stocking rate, feeding rate, etc. With an average conversion factor the estimated weight of fish in the pond at any time can be estimated by dividing the amount of feed already fed by the conversion factor. By using a constant conversion factor and a constant feeding rate the amount fed increases exponentially with time. The method involves stocking a known weight of fish. The fish are fed for a period (one or two weeks) at a given rate (3 percent of body weight per day). At the end of this period the weight of fish in the pond is calculated by dividing the amount of feed fed by the conversion rate. This weight of fish then serves as the new weight on which is based the amount of feed to be fed daily for the next period.

The frequency of feeding is also of importance in the nutrition of warm-water fish. Shell (Unpublished) at Auburn has shown that large *Tilapia mossambica* will efficiently convert feed up to 5 percent of body weight per day if fed this amount of feed in no less than five equal portions. If fed fewer times, consumption is reduced and conversion rates are poor. Prather (Unpublished) recommends that the daily amount of feed for channel catfish be given in two equal portions after the feeding rate reaches 22.4 kg pounds per ha per day.

5 REFERENCES

Allison, R., 1957 A preliminary note on the use of di-n-butyl tin oxide to remove tapeworms from fish. *Progr.Fish Cult.*, 19(3):128-30

Crawford, B., 1957 Propagation of channel catfish (*Ictalurus lacustris*) at state fish hatchery. *Proc.Conf.stheast.Ass.Game Commrs.*, 11:132-41

Dupree, H.K., 1960 Water soluble vitamins essential for the growth of channel catfish, *Ictalurus punctatus*. Dissertation, Auburn University, Auburn, Alabama, 92 p.

Hartley, W.E., 1966 Feeding channel catfish in Kansas. *Fish Farmer*, 1(3):5-8

Hastings, W.H., 1963 Physical and biochemical changes in feeds during processing. *Proc.Conf.stheast.Ass.Game Commrs.*, 17:203-8

__________, 1964a Catering for channel catfish. *Feedstuffs*, 36(23):25

__________, 1964b Fish feed processing research. *Feedstuffs*, 36(21):13

Jewell, M.E., E. Schneberger, and J.A. Ross, 1933 The vitamin requirements of goldfish and channel catfish. *Trans.Amer.Fish.Soc.*, 63:338-47

Krisnandhi, S. and E.W. Shell, 1965 Utilization of casein and soybean protein by channel catfish, *Ictalurus punctatus* (Raf.). *Proc.Conf.stheast.Ass.Game Commrs.*

Lewis, W.M., M. Anthony, and D. Helms, 1963 Selection of animal forage to be used in the culture of channel catfish. *Proc.Conf.stheast.Ass.Game Commrs.*, 17:364-7

Nail, M.L., 1962 The protein requirement of channel catfish, *Ictalurus punctatus* (Rafinesque). *Proc.Conf.stheast.Ass.Game Commrs.*, 16:307-16

Nelson, B., 1957 Propagation of channel catfish in Arkansas. *Proc.Conf.stheast.Ass.Game Commrs.*, 10:165-8

Phillips, A.M., Jr., A.V. Tunison and G.C. Balzer, 1963 Trout feeds and feeding. *Circ.U.S. Fish Wildl.Serv.*, (159):38 p.

Phillips, A.M., Jr., *et al.*, 1964 Cortland Hatchery report No.33 for the year 1964. *Fish.Res. Bull.N.Y.Conserv.Dep.*, (28):82 p.

Prather, E.E., Preliminary experiments on winter feeding small fathead minnows. Proc.Conf.
1957 stheast.Ass.Game Commrs., 11:249-53

————, Further experiments on feeds for fathead minnows. Proc.Conf.stheast.Ass.
1958 Game Commrs., 12:176-8

————, Channel catfish shows promise as farm pond sport fish. Highlts.agric.Res.,
1964 11(3):15 p.

Rogers, W.A., Preliminary attempts to increase midges (Tendipedidae-Diptera) in hatchery
1963 ponds. Proc.Conf.stheast.Ass.Game Commrs., 17:339-46

Swingle, H.S., Experiments on commercial fish production in ponds. Proc.Conf.stheast.Ass.
1954 Game Commrs., 8:69-74

————, Commercial production of red cats (speckled bullheads) in ponds. Proc.Conf.
1957 stheast.Ass.Game Commrs., 10:155-60

————, Experiments on growing fingerling channel catfish to marketable size in
1958 ponds. Proc.Conf.stheast.Ass.Game Commrs., 12:63-72

————, Estimation of standing crops and rates of feeding of fish in ponds. In
1967 Proc. FAO World Symposium on Warm-water Pond Fish Culture, May 18-25, 1966,
Rome, Italy. FAO Fish.Rep., 44.3:416-23

Tiemeier, O.W., C.W. Deyoe and S. Wearden, Supplemental pellet feeding of channel catfish.
1964 Rep.Prog.Kans.St.Univ., (97):10 p.

————, Effects on growth of fingerling channel catfish of diets containing two
1965 energy and two protein levels. Trans.Kans.Acad.Sci., 68(1):180-6

————, Experiments with supplemental feeds for channel catfish. In Proceedings,
1967 FAO World Symposium on Warm-water Pond Fish Culture, May 18-25, 1966, Rome
Italy. FAO Fish.Rep., 44.3:388-99

Tongsanga, S., Efficiency of three species of male tilapia, T. melanopleura (Dumeril),
1963 T. mossambica Peters, and T. nilotica (Linn.) when fed upon ground leaves of
kudzu, Pueraria thurbergiana. M.S. Thesis, Auburn University, Auburn, Alabama,
38 p.

Zobari, A., Experiments on feeds and rates of feeding the common carp, Cyprinus carpio
1955 Linnaeus in troughs. Dissertation, Auburn University, Auburn, Alabama, 102 p.

————, Incidence of B-complex avitaminosis among common carp raised in troughs.
1956 Progr.Fish Cult., 18(2):89-91

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III/E-1

INFLUENCE DE LA DISTRIBUTION DE NOURRITURE ARTIFICIELLE SUR LA MORTALITE DES JEUNES ALEVINS, LA CROISSANCE PRE-ADULTE ET LA MATURITE SEXUELLE D'*HETEROTIS NILOTICUS* ERH.

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INFLUENCE DE LA DISTRIBUTION DE NOURRITURE ARTIFICIELLE SUR LA MORTALITE DES JEUNES ALEVINS, LA CROISSANCE PRE-ADULTE ET LA MATURITE SEXUELLE D'HETEROTIS NILOTICUS ERH.

Résumé

L'auteur s'est préoccupé de définir l'influence de trois types de nourriture artificielle (tourteau d'arachides, graines de coton concassées et son de riz), sur la mortalité infantile, la croissance pré-adulte et la maturité sexuelle d'*Heterotis niloticus*.

Pour ce qui concerne la mortalité des jeunes alevins, le tourteau d'arachides doit être préféré à tout autre aliment. Il permet un pourcentage de survie supérieur.

Sur le plan de la croissance et du rendement pondéral, tourteau et graines de coton concassées sont supérieurs au son de riz. Le rendement unitaire maxima a été de 2.500 kg/ha/an.

Le bilan financier est très largement déficitaire dans le cas des deux premiers aliments. Le son de riz, par contre, permet une rentabilité acceptable de l'élevage. Non nourris, les *Heterotis* atteignent des tailles comparativement faibles et le bilan financier est inférieur à celui que l'on obtient avec le son de riz.

La maturité sexuelle est fonction du poids à un âge déterminé; la distribution de nourriture artificielle exerce une influence favorable et permet, dans certains cas, de l'avancer d'environ un an.

INFLUENCE OF ARTIFICIAL FEEDING ON MORTALITY OF YOUNG FRY, PRE-ADULTHOOD GROWTH AND SEXUAL MATURITY OF HETEROTIS NILOTICUS ERH.

Abstract

The writer tried to determine the influence of three types of artificial food (peanut-oil cakes, crushed cottonseed and rice bran) on mortality of young fry, pre-adulthood growth and sexual maturity of *Heterotis niloticus*.

Peanut-oil cake is preferable to any other food as it permits a higher rate of survival of young fry.

As regards growth and gain in weight, oil cake and crushed cottonseed give better results than rice bran. Maximum per unit yield was 2,500 kg/ha/year.

A financial deficit occurred with the use of the first two foods. Rice bran, on the other hand, makes the raising of young fry a paying proposition. If not fed artificially, the *Heterotis* only grow to relatively small size and the financial returns are lower than those obtained if rice bran is fed.

Sexual maturity depends on weight at a certain age; the distribution of artificial food has a favorable impact and in certain cases leads to the attainment of sexual maturity about one year before normal.

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INFLUENCIA DE LA DISTRIBUCION DE ALIMENTO ARTIFICIAL EN LA MORTALIDAD DE ALEVINES JOVENES, EN EL CRECIMIENTO PREADULTO Y EN LA MADUREZ SEXUAL DE HETEROTIS NILOTICUS ERH.

Extracto

El autor se ha preocupado de definir la influencia de tres tipos de alimentación artificial (torta de maní, semilla de algodón machacada y selvado de arroz) en la mortalidad juvenil, el crecimiento preadulto y la madurez sexual de Heterotis niloticus.

En lo que se refiere a la mortalidad de los jóvenes alevines, la torta de maní debe ser preferida a todo otro alimento y permite un porcentaje de supervivencia superior.

En el plano del crecimiento y del rendimiento ponderal, la torta y las semillas de algodón machacadas son superiores al salvado de arroz. El rendimiento unitario máximo ha sido de 2.500 Kg/ha/año.

El balance financiero es muy deficitario en el caso de los dos primeros alimentos. El salvado de arroz, por el contrario, permite una rentabilidad aceptable de la cría. Sin proporcionarles alimentos, los Heterotis alcanzan tallas relativamente bajas y el saldo financiero es inferior al que se obtiene con el salvado de arroz.

La madurez sexual es función del peso a una edad determinada; la distribución de alimento artificial ejerce una influencia favorable y permite, en ciertos casos, adelantarla en un año aproximadamente.

1 JUSTIFICATION DE L'ESSAI ET BUTS

Parmi les qualités que doit posséder un poisson que l'on désire utiliser en pisciculture intensive, l'acceptation de la nourriture artificielle et la possibilité d'un élevage à grande densité d'individus sont essentielles et immédiatement vérifiables.

Dans le cas particulier d'Heterotis niloticus, il était également important de vérifier l'hypothèse de la nourriture artificielle, cause des mortalités infantiles massives.

L'essai dont nous rendons compte ici a donc poursuivi un but triple :

1°- Mettre en évidence une éventuelle action défavorable de la nourriture artificielle sur les très jeunes alevins,

2°- Etudier comparativement la croissance de lots nourris avec le même poids de nourritures diverses pendant la vie pré-adulte des poissons,

3°- Déceler l'action de la nourriture artificielle sur l'âge de reproduction.

2 PROTOCOLE EXPERIMENTAL

2.1 Mise en place

Les divers travaux menés jusqu'alors à la Station de recherches piscicoles de Bouaké avaient permis de dégager une certitude : la fragilité extrême des alevins, surtout durant le tout jeune âge. Or, pour réaliser l'expérience présente, il fallait nécessairement connaître le nombre d'alevins avec une approximation suffisante et sans que la manipulation puisse être la cause principale des mortalités.

Nous avons donc imaginé l'appareil suivant qui nous a donné entière satisfaction. Il se compose d'une caisse en bois de 65 cm x 30 cm x 25 cm, ouverte à la partie supérieure et dont le fond est percé à une extrémité d'une ouverture à laquelle est adapté un robinet de 35 mm de diamètre. Cette caisse porte sur le fond et les grands côtés, des rainures se correspondant parfaitement et dans lesquelles coulissent des plaques métalliques. Celles-ci permettent de diviser la caisse en un certain nombre de compartiments égaux. La caisse est peinte en blanc à l'intérieur.

Dans le cas présent, nous avons procédé comme suit :

1°- La caisse est exempte de cloisons transversales. La vanne de vidange est fermée. On la remplit de 5 à 8 cm d'eau.

2°- Les alevins sont pris à l'épuisette en tulle moustiquaire et déposés avec précaution dans l'appareil.

3°- Par tâtonnements successifs, on essaie d'obtenir une répartition uniforme des alevins sur le fond.

4°- Une fois cette uniformité acquise, on laisse descendre rapidement le nombre de cloisons permettant de séparer l'essaim en autant de lots qu'on le désire.

Dans notre cas particulier, nous avions besoin de 5 lots d'importance numérique semblable. Par la suite, il est toujours possible de corriger les petites erreurs en soulevant légèrement une des cloisons de façon à favoriser le passage d'alevins d'un caisson à l'autre.

5°- On ajoute de l'eau dans la caisse afin d'obtenir une profondeur de 20 cm.

6°- Le premier caisson est vidé dans un seau par l'ouverture du robinet-vanne. Le deuxième et les suivants par enlèvements successifs des autres cloisons.

7°- Les 4 premiers lots de poissons sont placés dans leurs étangs respectifs.

8°- Le cinquième lot est sacrifié et ramené en laboratoire. C'est sur lui qu'ont été effectuées les opérations de comptage.

Nous avons testé l'appareil en sacrifiant délibérément plusieurs essaims.

L'erreur maxima encourue avec un seul observateur atteint 5%. On n'a pu relever aucune mortalité résultant de cette manipulation (1).

L'opération de mise en charge eut lieu le 27/7/1963. Les alevins étaient âgés d'environ 10 jours et étaient tous issus du même essaim. Les étangs D6, D7, D8 et D9 (surface : 4 ares), reçurent chacun 450 alevins ± 5%, soit entre 428 et 472 alevins.

2.2 Nourriture

Nous avons expérimenté avec les 3 types de nourriture habituellement utilisés à la Station : - étang D6 : son de riz,
étang D7 : graines de coton concassées,
étang D8 : tourteau d'arachide,
étang D9 : témoin, sans nourriture.

3 CONDUITE DE L'EXPERIMENTATION

Les quatre lots de poissons ont été élevés depuis le 27 juillet 1963 jusqu'aux 6-9 janvier 1965 dans les mêmes étangs.

La première vidange de contrôle fut retardée jusqu'aux 13-16 janvier 1964 afin qu'elle ne puisse être cause de mortalités massives parce qu'effectuée sur des poissons trop jeunes.

A ces dernières dates, une redistribution générale ayant pour but de compenser numériquement les chiffres inférieurs du témoin a été effectuée sur la base de 75 alevins de 70 grammes de moyenne par étang. Lors des vidanges, afin d'éviter des interférences dues à des effets à long terme de la nourriture, chaque lot de poissons était remis dans son étang d'origine après les contrôles en nombre et en poids. De même, pour réduire au maximum les chutes de croissance dues aux manipulations, les vidanges et remplissages se faisaient dans le laps de temps le plus court possible. Les organismes planctoniques plaqués au sol par le retrait des eaux ne subissaient pas d'assec supérieur à une heure. Il leur restait toujours suffisamment d'humidité pour survivre.

Des risques de surcharge étaient à craindre à partir de juillet 1964. Aussi, lors des vidanges de ce mois, il a été effectué un échantillonnage dans chaque lot et on n'a gardé que 50% des sujets. Ces derniers ont été choisis dans toute la gamme des tailles de façon à éviter une éventuelle sélection sexuelle. La première partie de l'expérience s'est terminée avec la première vidange, soit en janvier 1954. Nous esti-

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(1) Par la suite, nous avons utilisé cet appareil différemment. Comme il ne s'agissait plus de diviser un essaim en un certain nombre de lots d'importance numérique égale mais de connaître le nombre d'alevins qui le composait, on a opéré par divisions successives, le dernier lot était entièrement compté et multiplié par les chiffres 16, 32 ou 64 suivant le nombre de divisions.

Tableau I

Résultats chiffrés des vidanges des 13 - 16 Janvier 1964

N° d'étang	Traitement	Poids (en grammes)				Longueur moyenne en mm	Nombre total	% de mortalité (1)
		minimum	moyen	maximum	total			
D6	Son de riz	12	73,7	1.050	5.420	173,5	74	82,7 à 84,3
D7	Coton	10	77,1	325	11.809	183,1	153	64,3 à 67,6
D8	Tourteau	12	58,8	325	10.418	162,4	177	58,6 à 62,5
D9	Témoin	10	58,1	320	2.034	162,2	35	91,8 à 92,6

(1) Les chiffres inférieurs et supérieurs des % de mortalité sont calculés sur l'hypothèse de:

450 alevins - 5% (= 428)
450 alevins + 5% (= 472)

Tableau II

Résumé de la situation statistique

Age	Traitements comparés	Sigles	95%	90%
12 mois	Coton - Arachide	$L_1 - L_2$	-	-
	Coton - Son de riz	$L_1 - L_3$	+	+
	Coton - Témoin	$L_1 - L_4$	+	+
	Arachide - Son de riz	$L_2 - L_3$	+	+
	Arachide - Témoin	$L_2 - L_4$	+	+
	Son de riz - Témoin	$L_3 - L_4$	+	+
18 mois	Arachide - Coton	$L'_1 - L'_2$	-	-
	Arachide - Son de riz	$L'_1 - L'_3$	+	+
	Arachide - Témoin	$L'_1 - L'_4$	+	+
	Coton - Son de riz	$L'_2 - L'_3$	-	-
	Coton - Témoin	$L'_2 - L'_4$	+	+
	Son de riz - Témoin	$L'_3 - L'_4$	+	+

+ = différence significative

- = différence non significative

mions, en effet, qu'âgés de 6 mois, les alevins avaient échappé pour la plupart aux très grosses mortalités infantiles. Les résultats ultérieurs confirmèrent cette impression.

Pour la seconde partie de l'essai, nous avons effectué des vidanges de contrôle aux dates ci-après, déterminant des temps de croissance suivants :

14-19 janvier 1964	aux	10-14 avril 1964	: 3 mois
10-14 avril 1964	aux	15-18 juillet 1964	: 3 mois
15-18 juillet 1964	aux	6-9 janvier 1965	: 6 mois

A cette date, les Heterotis des lots ayant eu la meilleure et la plus mauvaise croissance ont été placés dans deux étangs de ponte différents où ils ont reçu la même nourriture qu'antérieurement et nous avons attendu les premières manifestations de l'instinct de reproduction.

Des contrôles biquotidiens de température ont été effectués dans les quatre étangs. Les mesures chimiques ont porté sur le pH, SBV, O_2 dissous et concentration en Ca (période : toutes les deux à trois semaines, puis tous les deux mois). Les prélèvements de planoton ont été faits mensuellement. Les seules différences décelables ont été : (1)

1°- une très légère tendance des étangs nourris à présenter un taux de saturation en O_2 inférieur (56 à 60% pour 70%);

2°- l'alimentation artificielle favorise nettement les rotifères;

3°- l'étang nourri au tourteau d'arachide a une production phytoplanctonique supérieure.

4 RESULTATS

4.1 Mortalité des jeunes alevins (Tableau I)

Les traitements les plus favorables ont été le tourteau d'arachide et les graines de coton concassées. Il n'y a entre eux qu'une différence faible, mais malgré tout réelle. Le nombre d'alevins pêchés en D8 est plus élevé, par contre, leur poids est légèrement inférieur.

Le son de riz ne semble pas constituer une nourriture très intéressante pour les alevins d'Heterotis. Le pourcentage de mortalité est nettement plus élevé.

Dans l'étang témoin, n'ont été retrouvés que 35 poissons. De toute évidence, ils ont eu faim.

Il est remarquable de constater que les poids individuels minima et maxima sont comparables d'un lot à l'autre, sauf dans D6 où un individu exceptionnel atteignait (à 6 mois), 1.050 g; mais ici également, le poisson venant immédiatement après dans l'échelle pondérale accusait 255 g sur la balance.

4.2 Croissance pendant les stades pré-adultes

4.2.1 Analyse mathématique des résultats

Lorsqu'il s'agit de comparer les moyennes de plus de deux échantil-

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(1) Reizer Christian - Hydrobiologie des étangs de Kokondekro. Influence de l'épandage d'engrais et de la distribution de nourriture sur les organismes planctoniques. (Rapport de diffusion restreinte, CTFT 1964).

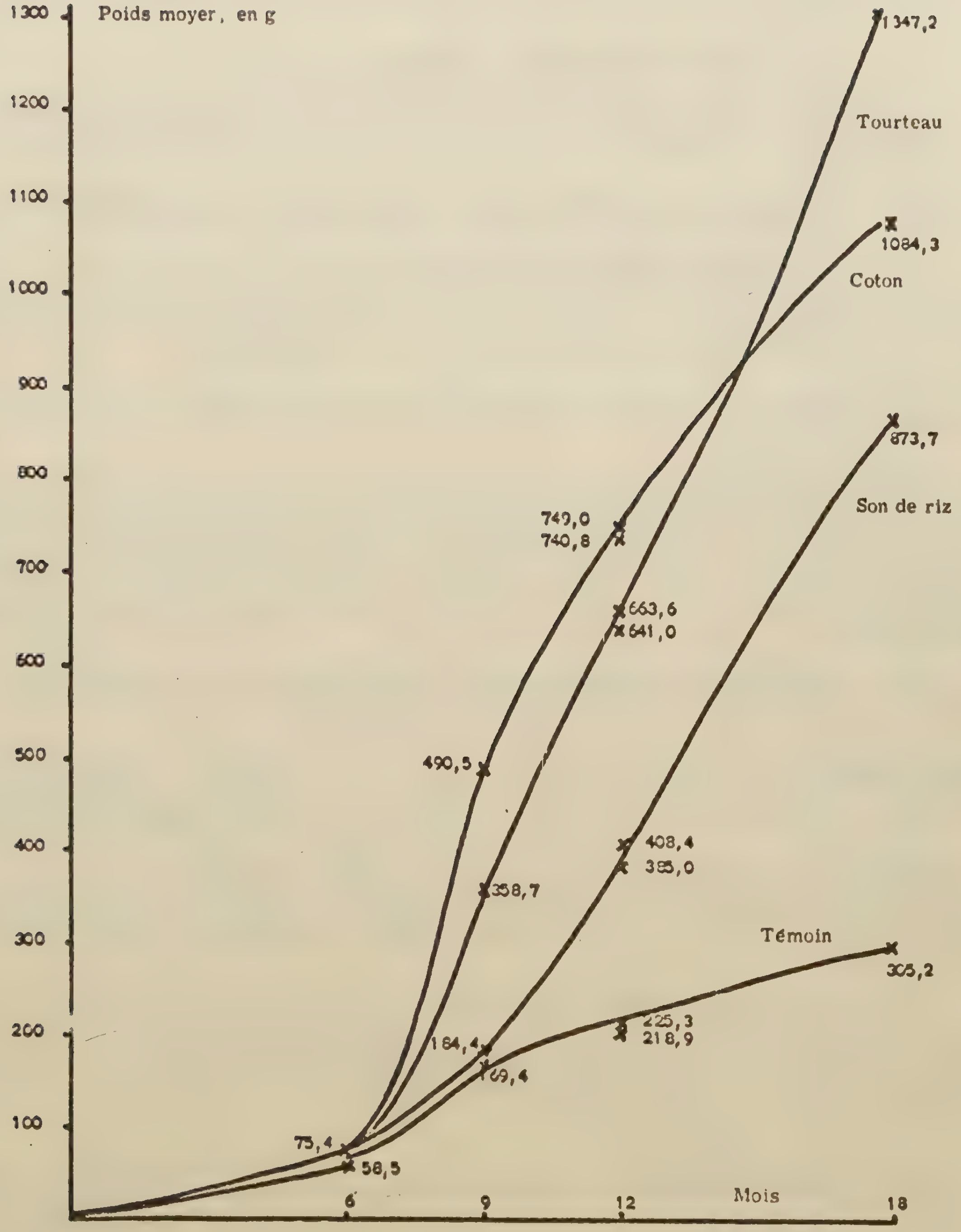

Fig. 1 Courbes de croissance en fonction de la nourriture (poids moyens individuels)

lons, on utilise habituellement la méthode de l'analyse de la variance. Celle-ci permet de juger en une seule opération de l'homogénéité de l'ensemble, mais elle ne permet pas de tester les relations entre deux échantillons à l'étude. Aussi nous avons préféré comparer les lots deux à deux par des tests d'homogénéité de moyennes (test "t") L_1 et L_2, L_1 et L_3, L_1 et L_4, L_2 et L_3, L_2 et L_4, L_3 et L_4.

Les calculs statistiques ont été conduits à partir des chiffres obtenus à 12 et 18 mois. Le résumé de la situation statistique est repris dans le Tableau II.

4.2.2 Interprétation des résultats

Aussi bien à 12 qu'à 18 mois, les lots nourris présentent des moyennes pondérales significativement plus élevées que celles du témoin.

A 12 mois, coton et arachide donnent des résultats statistiquement comparables. Par contre, ils assurent l'un et l'autre une meilleure croissance que le son de riz.

A 18 mois, coton et arachide sont toujours liés quoiqu'il y ait eu inversion, le tourteau prenant la tête. Ce dernier permet une croissance supérieure à celle du son de riz. Par contre, le coton est victime d'un ralentissement notable et sa moyenne n'est pas statistiquement différente de celle du son de riz.

Les courbes de croissance, quoique du même type sigmoïde, ont donc des allures différentes :

1°- Le coton permet un départ rapide mais son action se ralentit assez vite;
2°- le tourteau d'arachide a une action plus lente au départ mais cette dernière se maintient longtemps et marque même une tendance à l'accélération;
3°- avec le son de riz, on ne peut espérer un démarrage rapide de la croissance. A six mois, la moyenne était à peine supérieure à celle du témoin. Mais, par la suite, la courbe se redresse et à 18 mois, le poids moyen obtenu peut être considéré comme satisfaisant.

Ces différences pourraient s'expliquer assez bien par l'examen du cycle planctonique. En effet, celui-ci peut se résumer comme suit :

saison sèche : abondance de zooplancton, avec large dominance de Cyclops, quelques daphnidae. Des rotifères dans les étangs nourris. Les formes végétales sont peu nombreuses et peu abondantes : Cosmarium - Coelastrum - Pediastrum - Gloeocystis, etc..

saison humide : prédominance de plus en plus marquée du phytoplancton sur le zooplancton. Les cyclops semblent toujours aussi nombreux en valeur absolue, mais les espèces végétales dominent très nettement : Gloeocystis - Pediastrum - Botryococcus - Coelastrum.

Or dans les étangs nourris au tourteau et au coton, ce cycle semble exacerbé. L'eau a pris à partir de juillet-août une teinte verte dans toute son épaisseur. Des concentrations importantes de Gloeocystis apparaissent en surface. Il semble donc y avoir une relation directe entre le cycle planctonique et l'allure des courbes du graphique n° 1.

Malgré les difficultés que l'on éprouve pour effectuer des mesures quantitatives de plancton, notre impression à l'issue des échantillonnages échelonnés sur 18 mois est que la concentration va en croissant de D9, D6 à D7, D8. Or, les moyennes pondérales périodiques correspondent parfaitement à ces observations. On peut donc avancer l'idée que la croissance d'Heterotis niloticus, poisson microphage, est directement fonction de la quantité de plancton, surtout végétal, cette dernière étant elle-même dépendante de la qualité de la nourriture artificielle distribuée.

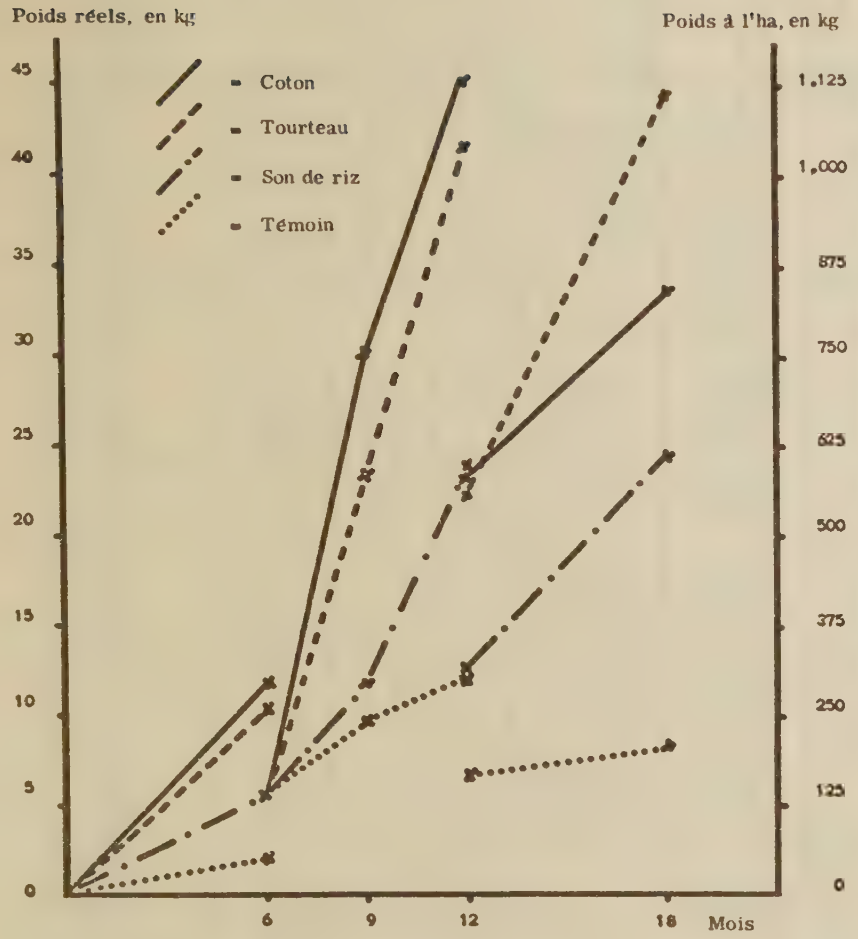

Fig. 2 Croissance des populations d'*Heterotis niloticus erh.*

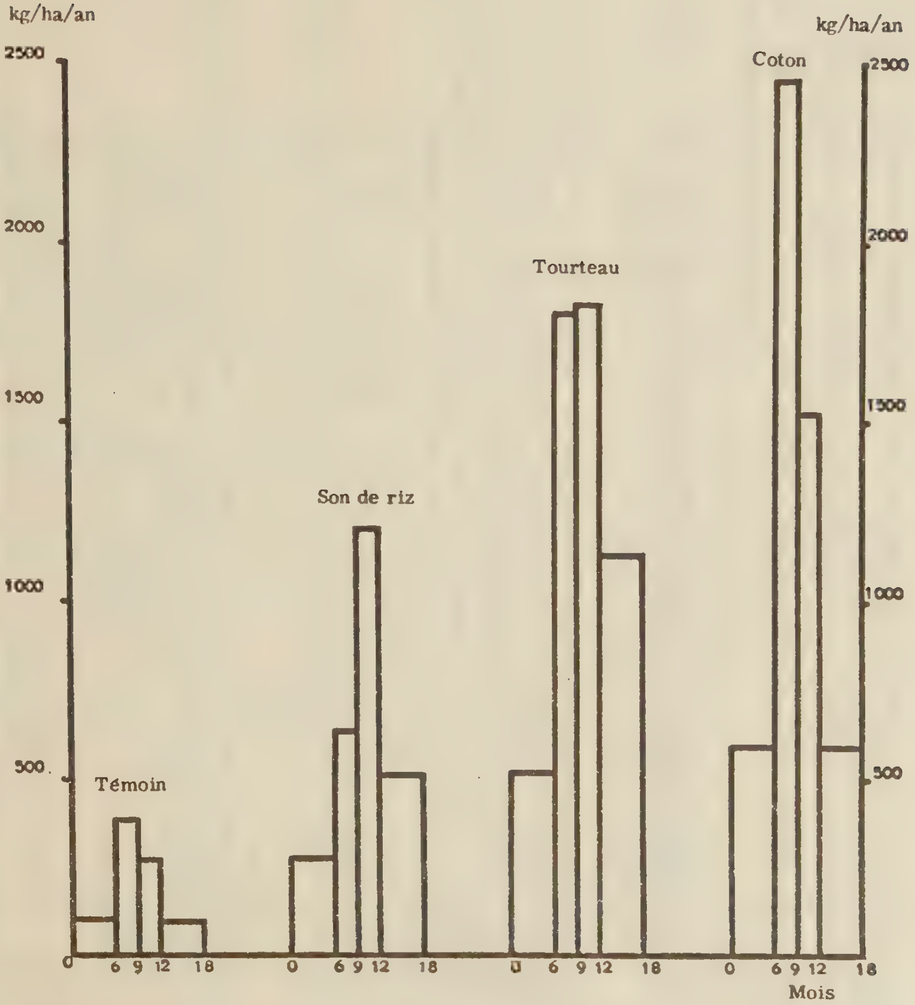

Fig. 2 bis Evolution périodique du rendement (nombre de kg par ha et par an)

Tableau III

Croissance en fonction de la nourriture artificielle

N° de l'étang	Nourriture	Dates	Opérations	Nombre	Poids (en grammes)				Quotient nutritif
					Maximum	Moyen	Minimum	Total	
D6	Son de riz	14/1/64	Charge	74	1.050	73,7	12	5.460	
		10/4/64	Vidange	64	1.650	184,4	35	11.805	40,3
		15/7/64	Vidange	62	2.250	385,0	80	23.870	38,8
		15/7/64	Charge	31	2.250	408,4	80	12.660	
		6/1/65	Vidange	28	3.030	873,7	70	24.465	72,2
D7	Coton	15/1/64	Charge	74	270	773,1	12	5.410	
		11/4/64	Vidange	61	1.200	490,5	175	29.925	10,6
		16/7/64	Vidange	61	1.790	740,8	250	45.190	30,6
		16/7/64	Charge	31	1.790	749,0	250	23.220	
		7/1/65	Vidange	31	2.530	1.084,3	180	33.615	85,4
D8	Tourteau	19/1/64	Charge	76	320	71,3	12	5.425	
		13/4/64	Vidange	65	970	358,7	85	23.315	14,7
		17/7/64	Vidange	65	1.630	641,0	160	41.570	25,4
		17/7/64	Charge	33	1.630	663,6	210	21.900	
		9/1/65	Vidange	33	2.545	1.347,2	510	44.460	39,7
D9	Témoin	19/1/64	Charge	77	320	70,3	10	5.415	
		14/4/64	Vidange	55	495	169,4	65	9.325	
		18/7/64	Vidange	55	730	218,9	70	12.040	
		18/7/64	Charge	28	730	225,3	70	6.310	
		9/1/65	Vidange	27	1.090	305,2	90	8.240	

La courbe du lot nourri aux graines de coton présente une décélération sensible à partir du 9ème mois. Or les quantités de plancton augmentent régulièrement jusqu'à la fin de l'expérience. Celle-ci se termine alors que les Gloeocystis crèvent en surface de l'étang. La croissance ne se ralentirait-elle pas à la suite de l'accumulation du gossypol dans les eaux ? Observation qui semble confirmée par d'autres effectuées dans une expérience différente.

Signalons enfin que les courbes de croissance affectent toutes l'allure sigmoïde type. Il semble pourtant que le ralentissement ne se soit pas encore marqué pour le lot nourri au tourteau d'arachides.

L'examen des graphiques 3 à 6 montre que l'augmentation du poids moyen est beaucoup plus une conséquence de l'étalement de la courbe que d'une élévation du mode pondéral. En fait, cette augmentation est donc due plus à une meilleure croissance des individus de taille supérieure que des individus de taille inférieure. Finalement, on constate que, dans un lot d'Heterotis issus des mêmes parents, nés le même jour, ayant subi le même traitement, se trouvent des individus pesant 10 à 20 fois plus que d'autres.

Exemple : D7, le 15/1/1964 : minimum = 12, maximum = 270
D8, le 19/1/1964 : minimum = 12, maximum = 160
le 13/4/1964 : minimum = 85, maximum = 970

Certains individus vraiment exceptionnels atteignent même des tailles records en un temps relativement court. Témoin le poisson à poids maximum trouvé en D6 :

le 14/1/1964 : 1.050 g à 6 mois
le 10/4/1964 : 1.650 g à 9 mois
le 15/7/1964 : 2.251 g à 12 mois
le 6/1/1965 : 3.030 g à 18 mois.

Cette observation appelle immédiatement deux remarques :

1°- Comme l'écrivait déjà Iltis (1), il est vraisemblable qu'il y a des possibilités réelles d'amélioration du cheptel Heterotis par simple sélection massale.

2°- Pour disposer d'une moyenne pondérale statistiquement valable, il est nécessaire d'expérimenter sur des lots nombreux d'Heterotis.

4.3 Rendement pondéral

La mise en charge initiale atteignait à peine 50 g. Elle peut donc être négligée.

Deux lots présentent un maximum de production entre 6 et 9 mois, coton et témoin. Les deux autres présentent un maximum plus tardivement entre 9 et 12 mois. Par la suite, tous les rendements diminuent. C'est donc entre 6 et 12 mois qu'Heterotis atteint son maximum de productivité et de croissance. Il semble donc, compte tenu du poids moyen individuel obtenu en ce laps de temps, que l'on n'a pas intérêt, en pisciculture intensive, à garder les Heterotis au-delà de un an.

Le maximum jamais atteint dans l'expérience l'est avec le coton. Il frôle les 2,5 tonnes/ha/an. Si l'on veut bien considérer qu'il s'agit là d'un élevage monospécifique et que la moyenne pondérale individuelle était de 490 g, on peut considérer ce résultat comme remarquable.

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(1) Iltis - Essai n° 10 - Observations sur le comportement des Heterotis niloticus à la Station de Kokondekro. Rapport de diffusion restreinte, 1961.

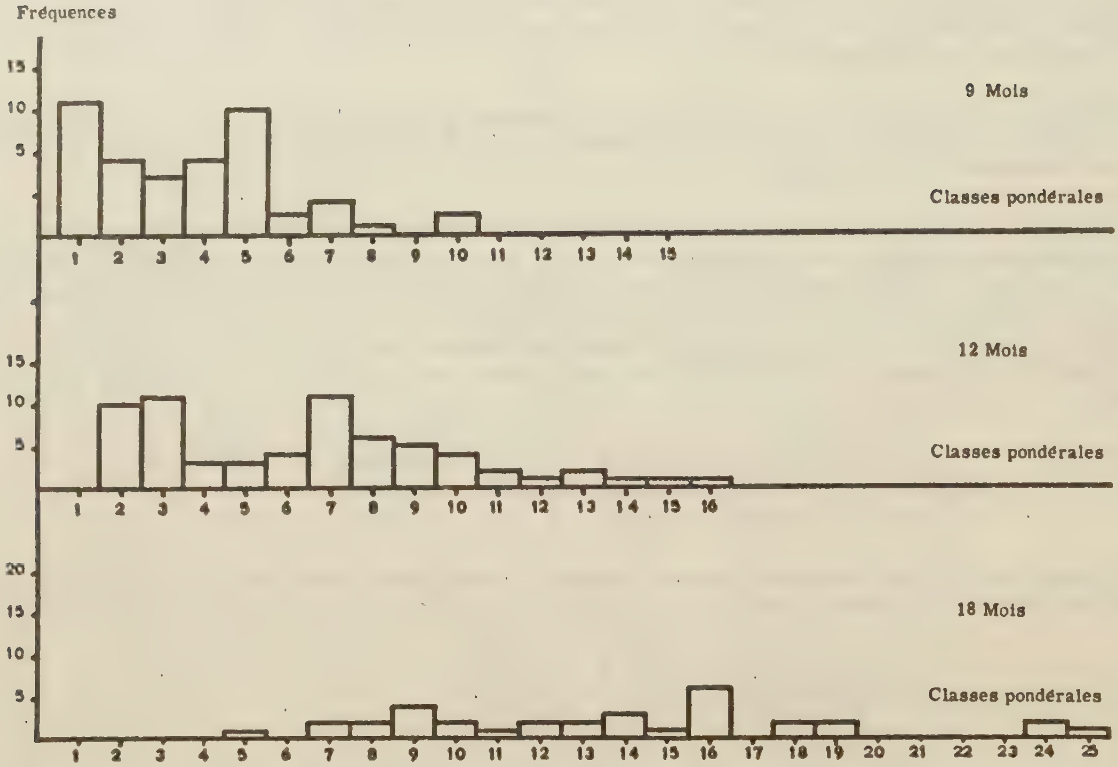

Fig. 3 Fréquences pondérales périodiques: tourteau d'arachide

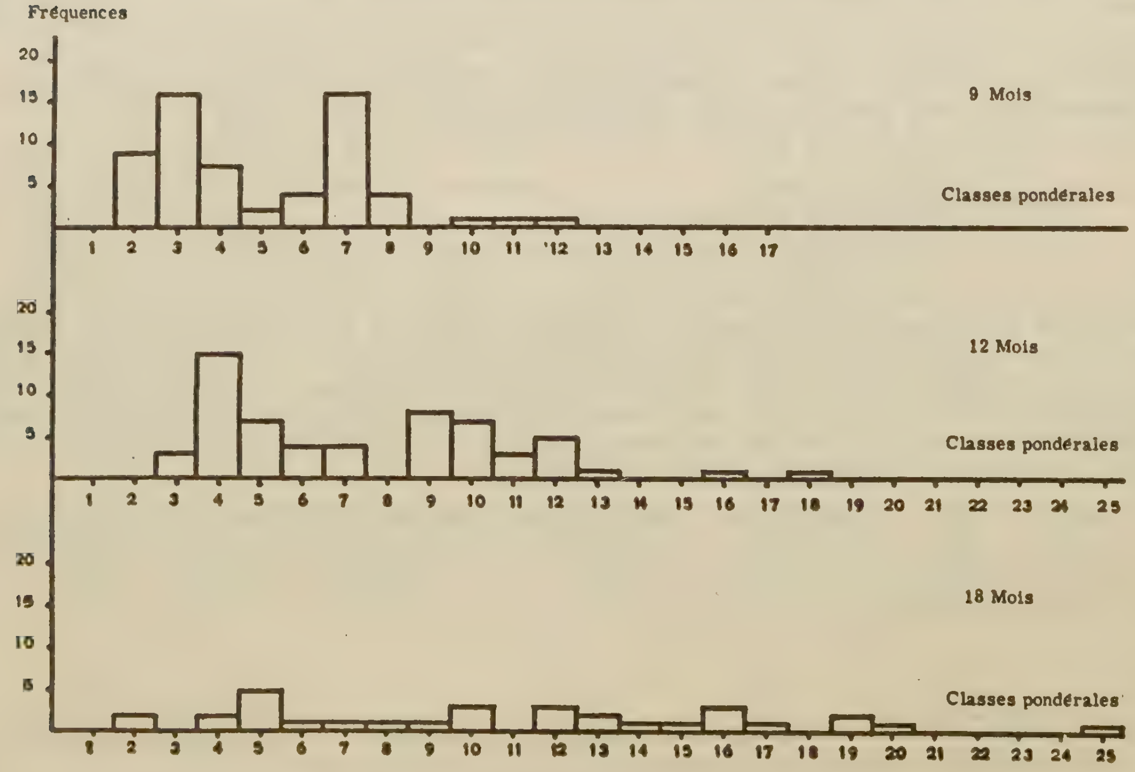

Fig. 4 Fréquences pondérales périodiques: graines de coton

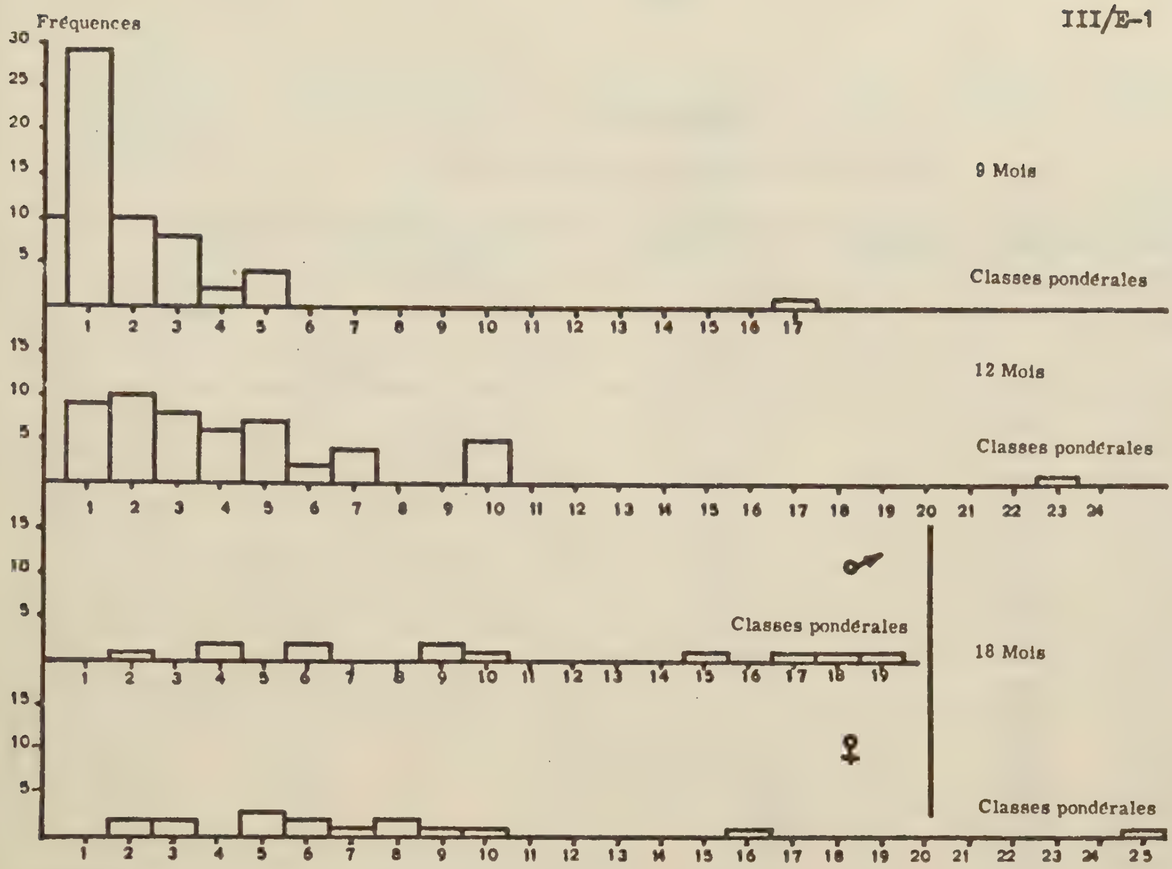

Fig. 5 Fréquences pondérales périodiques: son de riz

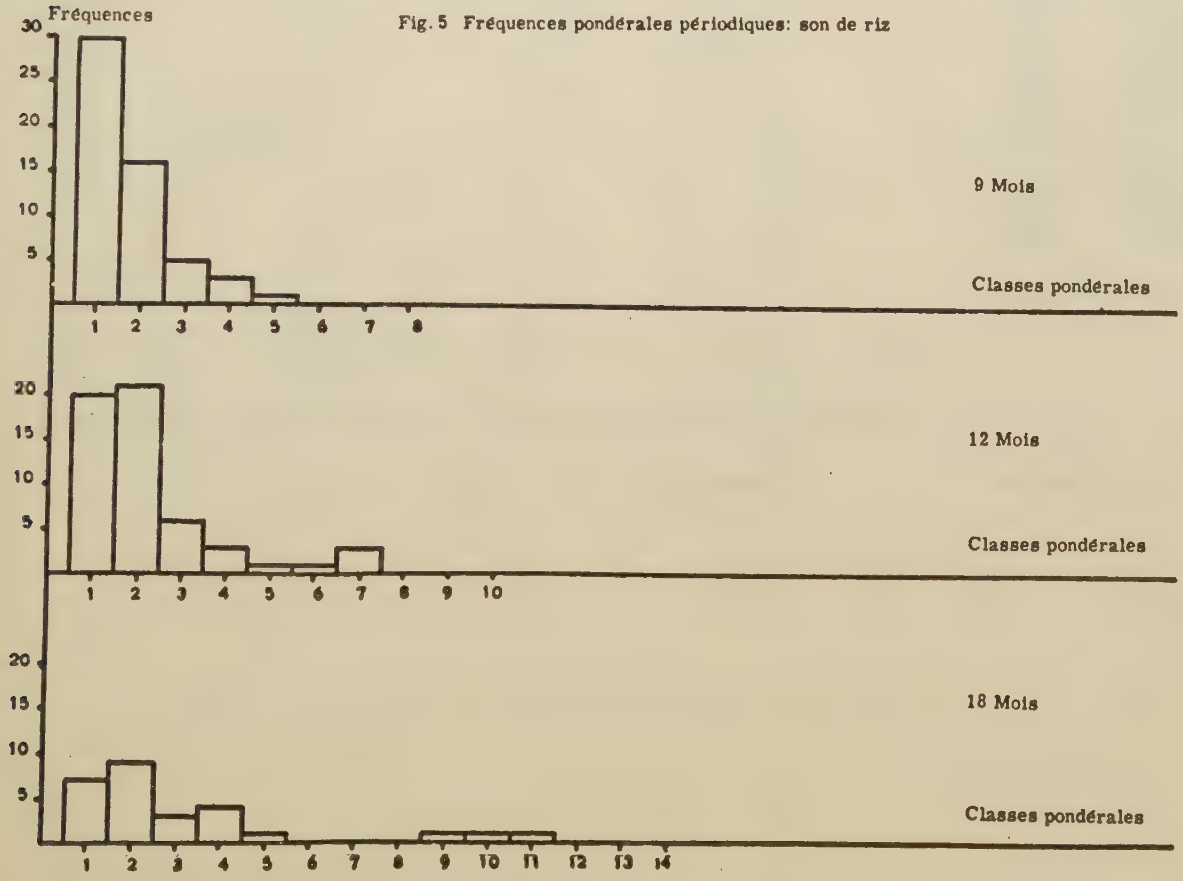

Fig. 6 Fréquences pondérales périodiques: témoin

Tableau IV

Fréquences pondérales périodiques

N°	Classes pondérales	Tourteau			Coton			Son de riz				Témoin		
	Limites en g	mois			mois			mois				mois		
		9	12	18	9	12	18	9	12	18		9	12	18
										M	F			
0	0 - 49							10						
1	50 - 149	16						29	14			30	20	7
2	150 - 249	9	10		9		2	10	15	I	2	16	21	9
3	250 - 349	7	11		16	3		8	8		2	5	6	3
4	350 - 449	9	3		7	15	2	2	6	2		3	3	4
5	450 - 549	15	3	1	2	7	5	4	7		3	1	1	1
6	550 - 649	2	4		4	4	1		2	2	2		1	
7	650 - 749	4	11	2	16	4	1		4		1		3	
8	750 - 849	1	6	2	4	2	1				2			1
9	850 - 949		5	4		8	1			2	1			1
10	950 - 1049	2	4	2	1	7	8		5	1	1			1
11	1050 - 1149		2	1	1	3								
12	1150 - 1249		1	2	1	5	3							
13	1250 - 1349		2	2		1	2							
14	1350 - 1449		1	3			1							
15	1450 - 1549		1	1			1			1				
16	1550 - 1649		1	6	1		3				1			
17	1650 - 1749						1	1		1				
18	1750 - 1849			2		1				1				
19	1850 - 1949			2			2			1				
20	1950 - 2049						1							
21	2050 - 2149													
22	2150 - 2249													
23	2250 - 2349			2					1					
24	2350 - 2449			1			1				1			
25	2450													
Totaux		65	65	33	62	60	31	64	62	12	16	55	55	27
										28				

M : Mâles F : Femelles

Tableau V

Rendement pondéral périodique

Traitement	0 à 6 mois				6 à 9 mois			
	Charge	Vidange	Rendement	Rdt/ha/an	Charge	Vidange	Rendement	Rdt/ha/an
Tourteau	-	10.418	10.418	520,9	5.425	23.315	17.890	1.789,0
Coton	-	11.809	11.809	590,4	5.410	29.925	24.515	2.451,5
Son de riz	-	5.460	5.460	273,0	5.460	11.805	6.345	634,0
Témoin	-	2.034	2.034	101,7	5.415	9.325	3.910	391,0
	9 à 12 mois				12 à 18 mois			
Tourteau	23.315	41.570	18.255	1.825,5	21.900	44.460	22.560	1.128,0
Coton	29.925	45.190	15.265	1.526,5	23.220	33.615	10.395	519,7
Son de riz	11.805	23.870	12.065	1.206,5	12.660	24.465	11.805	590,2
Témoin	9.325	12.040	2.715	271,25	6.310	8.240	1.930	96,5

Tableau VI

Rendement pondéral final à l'hectare

Traitement	Date de vidanges	Production		
		Partielle (kg)	Totale en 18 mois (kg)	Par ha et par an (kg)
Tourteau	19/1/1964 17/7/1964 9/1/1965	4.933 19.670 44.460	69.123	1.152,05
Coton	15/1/1964 16/7/1964 7/1/1965	6.399 21.970 33.615	61.924	1.032,22
Son de riz	14/1/1964 15/7/1964 6/1/1965	- 11.210 24.465	35.675	594,58
Témoin	19/1/1964 18/7/1964 9/1/1965	3.381 5.730 8.240	10.589	176,48

Il est vraisemblable que, si nous avions pu disposer d'étangs sensiblement plus grands, 10 à 20 ares, la productivité à charge égale eut été meilleure.

4.4 Rendement financier

Puisque nous étudions le poisson sur le plan "Pisciculture intensive", nous nous placerons délibérément dans le cas où les alevins auraient été fournis de l'extérieur par une station d'alevinage, à l'âge de 6 mois. Nous négligerons donc pour le moment :

- les frais occasionnés par la distribution de nourriture avant les vidanges de janvier 1964.
- l'investissement nécessité par la construction des étangs d'engraissement.

Il a été distribué les quantités suivantes de nourriture :

1ère période : 4 kg par jour ouvrable, soit	292 kg
2ème période : 6 kg par jour ouvrable, soit	468 kg
3ème période : 6 kg par jour ouvrable, soit	876 kg
Total	1.636 kg

Les prix de vente sur le marché de Bouaké sont fonction de la grosseur des poissons présentés :

- plus de 500 g	150 F CFA le kg,
- de 200 à 500 g	100 F CFA le kg,
- moins de 200 g	80 F CFA le kg.

Les vidanges ont chaque fois fourni des poissons appartenant à ces trois catégories. Le tableau VII en reprend le détail.

Il existe une différence fondamentale entre les trois aliments utilisés :

1°- le tourteau d'arachides est un sous-produit industriel employé dans l'élevage intensif du bétail. Sa qualité de produit usiné le rend extrêmement onéreux. Le bilan financier est donc très largement déficitaire.

2°- Les graines de coton concassées sont récupérées après défibrage. Mais elles ne peuvent malgré cela être considérées comme un déchet car leur teneur en huile les fait rechercher. Elles font l'objet d'un marché. Or, l'offre en graines non traitées contre les parasites est très faible en regard de la demande : le prix de vente est donc assez élevé. Le bilan financier sera ici aussi négatif.

3°- Le son de riz, par contre, est un déchet non récupérable. Son prix de vente est dérisoire. Le bilan financier est hautement favorable.

4°- Bien que le témoin n'ait reçu aucune nourriture et que, de ce fait, son prix de revient soit nul, le bilan financier est beaucoup moins favorable qu'avec le son de riz. C'est la conséquence des faibles poids totaux et individuels obtenus.

Il est donc de la plus haute importance de nourrir le poisson et d'utiliser à cette fin un produit de récupération à prix de vente nul ou très bas, c'est-à-dire d'un déchet non récupérable et ne bénéficiant d'aucun autre débouché.

Tableau VII

Rendement financier brut à 18 mois

Traitement	Dates	à 80 F		à 100 F		à 150 F		TOTAUX (en francs CFA)
		Poids	Prix	Poids	Prix	Poids	Prix	
Tourteau	17/7/1964			2.920	292	16.750	2.512	2.804
	9/1/1965					44.500	6.675	6.675
				2.920	292	61.250	9.187	9.479
Coton	16/7/1964			5.010	501	16.960	2.544	3.045
	7/1/1965			2.100	210	31.515	4.725	4.935
				7.110	711	48.475	7.269	7.980
Son de riz	15/7/1964	1.320	105	5.520	552	4.370	655	1.312
	6/1/1965			2.420	280	22.045	3.300	3.540
		1.320	105	7.940	792	26.415	3.955	4.852
Témoin	18/7/1964	2.100	168	2.380	238	1.350	202	608
	9/1/1965	1.795	143	2.965	296	3.480	522	961
		3.895	311	5.345	534	4.830	724	1.569

Tableau VIII

Rendement financier net à 18 mois (en francs CFA)

Traitement	Quantité nourriture(kg)	Prix unitaire	Prix total	Prix vente	Rendement (F)	Rendement/ha (F)
Tourteau	1.636	15	24.540	9.479	- 15.061	- 376.525
Coton	1.636	7	11.452	7.980	- 4.472	- 111.800
Son de riz	1.636	1	1.636	4.852	+ 3.216	+ 90.400
Témoin	-	-	0	1.569	+ 1.569	+ 23.535

4.5 Etude du sex ratio en relation avec la croissance

A l'issue des dix mois, nous avons disséqué les Heterotis du lot D6, nourris au son de riz. C'est en effet la seule méthode qui nous permette de connaître le sexe de ce poisson. Aucun caractère sexuel primaire extérieur, aucun caractère sexuel secondaire; telles sont les particularités d'Heterotis niloticus.

Les résultats de cette vérification sont consignés dans le tableau IX. Le nombre de femelles est un peu plus important que celui des mâles. Or, dans la nature, tous les échantillons ont rapporté 50% de chaque sexe. Nous nous abstiendrons donc de tirer des conclusions, le nombre de poissons dont nous disposions étant trop faible.

Apparemment, la croissance moyenne des mâles semble un peu supérieure à celle des femelles malgré l'appoint considérable que représente pour ces dernières l'individu exceptionnel de 3.030 g. Ceci peut provenir d'une différence de croissance. Elle peut aussi ne refléter que le hasard de l'échantillonnage. Il importe donc de tester l'homogénéité des deux moyennes en cause.

La première question qui se pose à l'observateur est de savoir s'il faut ou non tenir compte de la femelle de 3.030 g. Dans le cas présent, il s'agit indiscutablement d'un individu exceptionnel et sa présence risque de fausser nettement le test d'homogénéité. Nous sommes donc d'avis qu'il faut l'éliminer.

Avec des échantillons numériquement aussi faibles, le test d'homogénéité de moyennes exige l'emploi de la formule suivante (1) :

Variance de l'ensemble :

$$\sigma^2 = \frac{(X_1 - \bar{X}_1)^2 + (X_2 - \bar{X}_2)^2}{n_1 + n_2 - 2} = \frac{3.926.625 + 1.979.810}{12 + 16-2} = 227.170,5$$

La variance standard de la différence des moyennes est alors :

$$s_d^2 = \sigma^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right) = 227.170,5 \left(\frac{1}{12} + \frac{1}{16}\right) = 33.129,0$$

et l'écart type est :

$$s_d = \sqrt{s_d^2} = \sqrt{33.129} = 182,0$$

Appliquons le test de Student : $t = \frac{\bar{X}_1 - \bar{X}_2}{s_d} = \frac{997,2 - 631,0}{182,0} = 2,01$

On lit dans la table de "t", que le seuil $T\,\gamma$ correspondant, pour une sécurité de 95% à $\gamma = (n_1 + n_2 - 2) = 26$ degrés de liberté est $T_{26} = 2,06$. $t = 2,01$ est inférieur à $T_{26} = 2,06$. La population peut donc être considérée comme homogène.

En termes clairs, cela signifie que la différence observée entre les moyennes pondérales des deux lots n'est pas significative et peut être due au hasard. Il est évident que, dans le cas présent, cette conclusion est la conséquence de la grande dispersion qui existe autour de la moyenne de chacun des lots.

4.6 Maturité sexuelle

Lors de la vidange finale, nous avons réservé le lot ayant eu la meilleure

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(1) Lamotte, M. - Initiation aux méthodes statistiques en biologie. p.77-99. Cas des petits échantillons.

Tableau IX

Croissance comparée des mâles et des femelles

MALES			FEMELLES		
x_1	$x_1 - \bar{x}_1$	$(x_1 - \bar{x}_1)^2$	x_2	$x_2 - \bar{x}_2$	$(x_2 - \bar{x}_2)^2$
1.880	882,5	778.806.25	1.645	1.014,0	1.028.196.00
1.835	837,5	701.406.25	965	334,0	111.556.00
1.710	712,5	507.656.25	880	249,0	62.001.00
1.500	502,5	252.506.25	835	204,0	41.616.00
1.045	47,5	2.256.25	765	184,0	17.956.00
930	67,5	4.556.25	710	79,0	6.241.00
900	97,5	9.506.25	645	14,0	196.00
570	427,5	182.756.25	640	9,0	81.00
560	437,5	191.406.25	510	121,0	14.641.00
445	552,5	305.256.25	490	141,0	19.881.00
370	627,5	393.756.25	460	171,0	29.241.00
225	772,5	596.756.25	260	371,0	137.641.00
			250	381,0	145.161.00
			240	391,0	152.881.00
			170	461,0	212.521.00
n_1 = 12 $\bar{x}_1$ = 997,2		Σ = 3.926.625	n_2 = 15 $\bar{x}_2$ = 631,0		Σ = 1.979.810

croissance et celui ayant eu la plus mauvaise, soit, d'une part "tourteau d'arachides", d'autre part "témoin". Ces poissons furent placés dans deux étangs de ponte de 2,5 ares, respectivement E5 et E4 où on continua à leur distribuer la même nourriture qu'auparavant.

Les premières manifestations sexuelles eurent lieu en E5 (lot nourri) vers le 13 juin 1965, avec la construction de deux nids. Les alevins apparurent le 16 juin, soit sensiblement en même temps que chez les Heterotis plus âgés placés dans les mêmes conditions.

Par contre, fin septembre, l'autre lot (témoin) n'avait encore donné aucun signe tangible de maturité sexuelle. Comme la saison de reproduction tire à sa fin, il est vraisemblable qu'il faudra attendre au mieux 1966 pour que les plus gros spécimens se reproduisent.

La maturité sexuelle semble donc être fonction non seulement de l'âge, mais également du poids des poissons. La rapidité de croissance pendant la période pré-adulte paraît exercer une influence déterminante sur l'âge de reproduction.

5 CONCLUSIONS GENERALES

5.1 Mortalité des alevins

Afin de réduire à un taux acceptable la mortalité des jeunes alevins, il est absolument indispensable de leur distribuer de la nourriture artificielle.

Dans l'expérience présente, la supériorité du tourteau d'arachides sur les graines de coton n'était pas manifeste. Néanmoins, à différentes occasions, nous avons remarqué que les graines de coton non consommées se décomposaient très mal et formaient parfois une couche sur le fond des étangs. Les fermentations qui en découlaient lors de la remise sous eau suivante étaient dans ce cas catastrophique pour les jeunes alevins.

A cause de ces mortalités "a posteriori", il est donc fortement indiqué d'utiliser le tourteau d'arachide pour alimenter les très jeunes alevins.

Il n'est pas nécessaire, sur le plan pratique, de garder les alevins jusqu'à 6 mois dans les étangs d'alevinage. Ils peuvent être déversés vers 3 mois 1/2 dans les pièces d'eau d'engraissement.

5.2 Croissance pré-adulte

Tant pour obtenir une production acceptable que des poids individuels marchands, il s'avère bénéfique d'apporter aux Heterotis pré-adultes de la nourriture artificielle.

Afin de rentabiliser au mieux cet élevage, il est absolument nécessaire d'utiliser des déchets sans valeur marchande. Dans le cas particulier de l'expérience, le son de riz a donné le meilleur rendement financier, ce qui ne signifie pas qu'il soit le seul produit utilisable.

La croissance d'Heterotis semble dépendre autant du cycle planctonique que de la nourriture artificielle. La quantité de plancton est bien entendu fonction de la qualité de cette nourriture artificielle.

L'augmentation du poids moyen avec le temps apparaît liée à une meilleure croissance des gros individus. Finalement, on trouve dans un même lot des poissons pesant

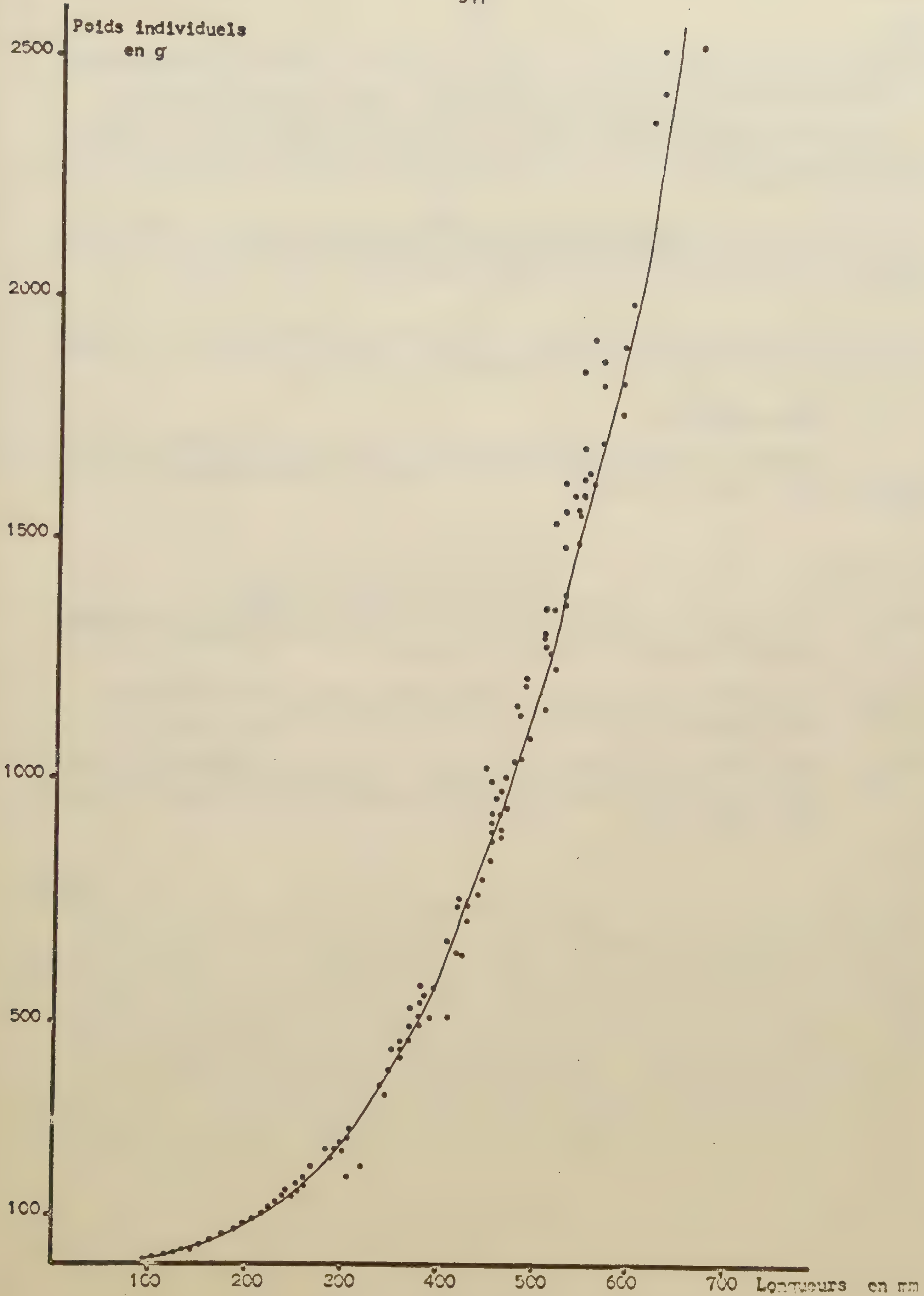

Fig. 7 Courbe longueur/poids

10 ou 20 fois plus que d'autres. Il est donc important de réaliser les expériences avec des lots comportant de nombreux individus.

En élevage monospécifique et en petits étangs, le rendement pondéral à l'ha peut atteindre 2,5 tonnes/an lorsque l'on nourrit avec des graines de coton. On pourrait vraisemblablement augmenter encore cette production en utilisant des étangs d'engraissement plus grands.

Le maximum de production en poids est atteint entre 6 et 12 mois. Comme à l'âge d'un an les Heterotis présentent un poids moyen qui les rend négociables, on n'a donc pas intérêt en pisciculture intensive, à prolonger leur élevage au-delà de cette période.

Les mâles ont un taux de croissance statistiquement semblable à celui des femelles. En cherchant à améliorer le cheptel par simple sélection massale, on ne risque pas d'effectuer une sélection sexuelle au bénéfice des premiers.

5.3 Maturité sexuelle

La maturité sexuelle apparaît dépendre plus du poids des poissons que de leur âge. On peut l'avancer d'environ un an en plaçant les Heterotis dans des conditions favorables à leur croissance.

6 REFERENCES

Iltis, A., 1961 Essai n° 10 - Observations sur le comportement des Heterotis niloticus à la Station de Kokondekro. Nogent sur Marne, Centre Technique Forestier Tropical (Rapport de diffusion restreinte)

Reizer, C., 1964 Comportement et reproduction d'Heterotis niloticus en petits étangs. Bois For.Trop.,(95):49-60

Reizer, C. 1964 Hydrobiologie des étangs de Kokondekro. Influence de l'épandage d'engrais et de la distribution de nourriture sur les organismes planctoniques. Nogent sur Marne, Centre Technique Forestier Tropical (Rapport de diffusion restreinte)

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STUDIES ON THE RATE OF FOOD PASSAGE IN THE INTESTINE OF LABEO ROHITA (HAM.), CIRRHINA MRIGALA (HAM.), AND CATLA CATLA (HAM.)

by

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Abstract

'Major carps' of India, comprising mainly *Labeo rohita*, *Cirrhina mrigala*, and *Catla catla*, constitute a group of most important fresh-water food fishes cultured on a large scale in the country. One of the problems in their culture is the determination of suitable diets to obtain maximum growth rates. Their natural food has been determined by several workers by examining gut contents and it has been shown that they are capable of ingesting a wide range of food materials. To what extent these are utilized is, however, not known. In the present study the rate of passage of various items of food normally fed upon in nature, in the intestine of these species, was investigated. Their amyloclastic and proteolytic activities were also determined so as to explore the relationship between rate of passage of food and efficiency of digestion. This investigation has provided an index of the extent of utilization of different food items by 'major carps'.

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ETUDE SUR LE TAUX DE PASSAGE DES ALIMENTS DANS LES INTESTINS DE LABEO ROHITA (HAM.), CIRRHINA MRIGALA (HAM.) ET CATLA CATLA (HAM.)

Résumé

Les "major" carpes indiennes, notamment *Labeo rohita*, *Cirrhina mrigala* et *Catla catla*, constituent un très important groupe de poissons d'eau douce élevés sur une grande échelle dans le pays. L'un des problèmes que pose leur élevage consiste à déterminer le régime alimentaire approprié pour obtenir le taux de croissance maximum. Leur alimentation naturelle est connue par les travaux de plusieurs chercheurs qui ont examiné le contenu des intestins, et il a été constaté que ces espèces sont capables d'ingérer les aliments les plus divers. Toutefois, on ne sait pas dans quelle mesure ces aliments sont assimilés. Des recherches ont été faits sur le taux de passage des différents aliments naturels dans les intestins de poissons des espèces considérées. Leurs fonctions amyloclastiques et protéolytiques ont également été étudiées afin d'établir le rapport entre le taux de passage des aliments et l'efficacité de la digestion. A la suite de ces études il a été établi un index du degré d'utilisation des différents aliments par les "major" carpes indiennes.

ESTUDIOS SOBRE EL PASO DE ALIMENTOS EN EL INTESTINO DE LABEO ROHITA (HAM.) CIRRHINA MRYGALA (HAM.) Y CATLA CATLA (HAM.)

Extracto

Las carpas principales de la India, formadas principalmente por *Labeo rohita*, *Cirrhina mrygala* y *Catla catla*, constituyen un grupo de peces comestibles de agua dulce muy importante, cultivado en gran escala en el país. Uno de los problemas de su cultivo es la determinación de la alimentación adecuada para obtener los máximos coeficientes de crecimiento. Su alimentación natural ha sido determinada por varios especialistas examinando los contenidos intestinales, y se ha comprobado que son capaces de ingerir una gran variedad de alimentos. En el presente estudio se ha investigado la cantidad de los varios tipos de alimentos proporcionados normalmente en la naturaleza que pasa al intestino de estas especies. Se han determinado también sus actividades amiloclásicas y proteolíticas a fin de explorar la relación entre la cantidad de alimentos que pasan al intestino y la eficacia de la digestión. Esta investigación ha proporcionado un índice del grado de utilización de los distintos tipos de alimentos por estas carpas principales.

1 INTRODUCTION

In India, three species of carps, Catla catla, Labeo rohita, and Cirrhina mrigala, belonging to the group popularly known as 'major carps', are of prime importance in fish culture. They are likely to be cultured on a much larger scale in the future, now that breeding can be induced by hormone injection. The great potentialities of major carp culture suggest that they should be subjected to the same kinds of studies as farm animals; to find, for example, which of their natural foods are utilized most efficiently for flesh production.

In fishes, although a considerable amount of work has been done on the anatomy and histology of the alimentary canal, comparatively little is known about the physiological aspects of digestion. The literature bearing on the enzyme equipment of different species has been reviewed by Yung (1899), Sullivan (1907), Yonge (1937), Vonk (1937, 1941), and Barrington (1942 ; 1957). However, the study of the rate of digestion "in vivo" seems to be a new approach to the nutritional physiology of fishes. Moreover, the previous observations on the rate of passage of food in fishes are on species having a stomach (Weinland, 1901; van Slyke and White, 1911; Dobreff, 1927; Karpevitch and Bokoff, 1937; Menon and Kewalramani, 1959; Hirao et al., 1960; Molnar and Tolg, 1962). Stomachless species have as yet been little studied, with the exception of work by Maltzan (1935) and Sokolcv and Chvaliova (1936).

Studies were therefore undertaken on the rate of passage of various foods, normally eaten in nature, through the intestine of Labeo rohita, Cirrhina mrigala and Catla catla. The amyloclastic and proteolytic activities of intestinal mucosa and the associated digestive glands were also to be determined, to explore a relationship, if any, between the rate of food passage and the efficiency of digestion. Previous work on the anatomy and histology of the alimentary canal of these species (Sarbahi, 1940; Ahsan-ul-Islam, 1949; Kapoor, 1953), had shown the absence of a stomach and presence of an unorganized and intrahepatic pancreas. The examination of their gut contents (Mookerjee, 1945; Mookerjee and Ghosh, 1945; Mookerjee and Das, 1945; Chacko and Kurian, 1950-51; Begum, 1959; George, 1963) had shown that they are capable of ingesting a variety of plankters and higher aquatic plants. To what extent these food items could be digested was, however, not known.

2 MATERIALS

Live specimens of Labeo rohita, Cirrhina mrigala, and Catla catla, were obtained from a fresh-water pond near Bombay and transported to large aquarium tanks (3.3 x 1.3 x 1.3 m) with fresh-water circulation at the Taraporevala Aquarium, attached to the Taraporevala Marine Biological Research Station, Bombay. Specimens of about 45 cm length, nearly one year old, were selected both for the study of rate of food passage and for determining the activity of digestive enzymes.

Live plankters, required as food for the fishes, were collected from stagnant pools around Bombay, with as far as possible, near monoculture blooms of the respective plankters.

3 METHODS

3.1 Determination of rate of food passage

Fishes were first kept in a large aquarium tank (3.3 x 1.3 x 1.3 m) for four or five days to acclimatize them to aquarium conditions. They were then transferred to a large experimental tank (3.0 x 0.7 x 0.7 m) containing filtered fresh water in circulation, and starved there for a week to ensure the complete evacuation of the intestine.

For the determination of the rate of passage of different food items, starved fishes were force-fed on nearly equal quantities of each food item separately, and the passage and condition of the food was examined after a lapse of different intervals. Fishes were anaesthetized before force-feeding, so as to be able to introduce a known quantity of each food item into the intestine. Preliminary experiments with M.S.222 (tricaine methanesulphonate, Sandoz) for anaesthetizing fishes for handling and force-feeding, showed that 50 ml of

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Table I

The retention of various food items in the intestine of _Labeo rohita_, _Cirrhina mrigala_ and _Catla catla_, of about 45 cm length and nearly one year old.*

	Food item	Retention time in hours		
		Labeo rohita	_Cirrhina mrigala_	_Catla catla_
1	_Microcystis_	48 to 54	54 to 60	42 to 48
2	_Anabaena_	48 to 54	54 to 60	48
3	_Scendesmus_	48 to 54	54	48
4	_Chlorella_	48	54 to 60	48
5	_Spirogyra_	36	24	42
6	_Ulothrix_	36	24	42
7	_Anacharis_	42	36	48 to 54
8	_Hydrilla_	42	36	48 to 54
9	_Vallisneria_	42	36	48
10	_Ottelia_	42	30 to 36	48
11	_Lemna_	30	24	30 to 36
12	Decayed _Microcystis_	36	30	42
13	Decayed _Anacharis_	36	30	42 to 48
14	_Daphnia_	24 to 30	24	18
15	Rotifer _Brachionus_	24	18 to 24	18
16	_Cyclops_ and _Diaptomus_	24 to 30	24	18
17	_Cypris_	36	30	24 to 30
18	Mosquito larvae	42	36 to 42	30 to 36
19	Chopped prawn	54	48 to 54	42 to 48
20	Chopped prawn (without chitin)	36	30 to 36	30

* Three readings were taken in each experiment

1 percent M.S.222 solution in 25 litres of water was necessary. A known quantity of a food item was then forced directly into the intestinal bulb of the fish by a soft plastic tube attached to a 60 ml syringe. The whole process of anaesthetization and feeding was over within about five minutes, and recovery was immediate with no after-effects. In the case of higher aquatic plants, a weighed quantity was placed by forceps near the gullet and pushed into the intestinal bulb by a soft plastic tube. Chopped prawn was force-fed in a similar manner. Vomiting seldom occurred; if it did, then such specimens were rejected. The fed fish were returned to the experimental tank. The temperature of the tank water varied from 28°C to 30°C, throughout the investigation. After the requisite period, the fish was killed by pithing, and the intestine was immediately ligatured at various places so as to be able to locate exactly the part where the food was lying. The distance traversed by the food was noted, and the recovered food was also examined microscopically to note the changes in its condition, if any, due to the action of the digestive enzymes of the fish.

3.2 Concentrations of amyloclastic and proteolytic enzymes in the three species

For the preparation of enzyme extracts of intestinal mucosa and liver, the freshly killed one-year old specimens of nearly 45 cm length were used. For extracting amylase and lipase, iced distilled water was used as a medium, whereas alcohol was used for the extraction of proteases, in the proportion of 10 parts by volume of extracting solvent to one part by weight of mucosa. The amyloclastic and proteolytic activities of the extracts were studied using one percent starch solution and 10 percent alkaline casein solution, respectively, at a temperature of 37°C, and at a pH 7.0 for amylases and pH 8.5 for proteases. The possibility of the presence of cellulase was investigated, using one percent carboxymethyl cellulose solution, as a substrate.

4 OBSERVATIONS

The times taken by different food items to reach the hindmost end of the intestine are given in Table I and the amyloclastic and proteolytic activities per unit weight of mucosa of different parts of intestine and associated digestive glands are given in Table II. The analysis of the data shows that in individuals of nearly the same size of the same species, and under similar experimental conditions, the rate of passage of different food items varies considerably with the kind of food. The algae, Microcystis, Anabaena, Scendesmus and Chlorella, were retained in the intestine for a longer time than the filamentous algae, Spirogyra and Ulothrix. It is interesting to note that the former were always recovered in the hindmost part of the intestine, in a totally unchanged condition, while the latter were appreciably digested; their cell walls were broken and the cell contents were not seen, probably being consumed due to the action of the digestive enzymes.

Higher aquatic plants were also retained for varying periods in the intestine of each species, and were digested to a different extent. Anacharis, Hydrilla, Ottelia, and Vallisneria, were retained for a considerably longer time in the intestine of each species, than Lemna. The major portion of all these higher aquatic plants consists of thin-walled chlorenchymatous cells. Most of these cells were found to be acted upon by the digestive enzymes. Lemna, which is very thin and the softest among all the plants studied, was digested almost completely. But in the case of other plants, which are comparatively coarse, some cells were always recovered even in the hindmost part of the intestine in an undigested condition, probably because the cell walls were covered with some material not amenable to the digestive process.

Since the major portion of the food of these species consists of plant-matter, the possibility of a cellulase being secreted by the alimentary canal or digestive glands was investigated, but no cellulase was found.

Table II

Time (in hr) required to digest 5 ml starch solution (1 percent) by extracts from equal weights of intestinal bulb, intestine and liver tissue by Indian major carps

Species	Intestinal bulb	Intestine		Liver
		Anterior half	Posterior half	
L. rohita	9.25	2.75	2.58	1.33
C. mrigala	4.33	1.50	2.41	0.58
C. catla	10.41	9.75	18.66	1.00

Table III

Weight (in mg) of amino acids released from 10 percent casein solution in 24 hours by enzyme extracts from various parts of the digestive tracts of Indian major carps

Species	Intestinal bulb	Intestine		Liver	Bile
		Anterior half	Posterior half		
L. rohita	1.40	5.32	8.08	16.80	3.92
C. mrigala	8.96	9.24	6.32	9.24	7.28
C. catla	9.36	9.24	9.52	10.64	5.60

Microcystis when given fresh passed out undigested, but decayed *Microcystis* was digested to a considerable extent, since most of the cells were found acted upon by the digestive enzymes, and this passed at a faster rate than fresh *Microcystis*. The digestion of *Anacharis* was also more, as well as faster, when it was given in a decayed condition. The decomposition probably breaks down some resistant material in the cell wall and so exposes the cell-contents to the action of the digestive enzymes. In the absence of cellulase, the breaking of the cell walls of fresh as well as decayed plant matter may possibly be due to the bacterial action.

Crustacean zoo-plankters *Daphnia*, *Cyclops*, *Diaptomus*, and *Cypris*, were digested rapidly except for the outer thin chitinous shell, but chopped prawn and mosquito larvae, with a more thickly chitinized exoskeleton, were retained for a longer time in the intestine. The chitinous exoskeleton of all these animal foods was always recovered, even in the hindmost part of the intestine, in a totally unchanged condition, probably due to lack of chitinase. This is supported by the observation (Table I) that when prawn was given after removing the exoskeleton, it was retained for a shorter time in the intestine.

Comparing the rate of food passage in these three species, it was found that in individuals of about 45 cm length, under similar experimental conditions, the passage of partially digestible plant matter was fastest in *Cirrhina mrigala*, slower in *Labeo rohita*, and slowest in *Catla catla*. The totally indigestible plant matter (Table I), however, passed at a more or less similar rate in the three species. Thus, the indigestible plant matter was retained for the longest time in *Cirrhina mrigala* which has the longest intestine, and for the least time in *Catla catla*, which has the shortest intestine. Thus under similar experimental conditions, the passage of a given food item would be expected to be directly proportional to the length of the intestine. This would mean that the food passage should be slowest in *Cirrhina mrigala*. However, the results show that the passage of digestible plant matter is fastest in *Cirrhina mrigala*. Obviously some other factor, other than the length of the intestine, is affecting the food passage. This factor is probably the difference in the concentration of amyloclastic enzymes in these species.

Tables II and III give the concentration of digestive enzymes per unit weight of mucosa of different parts of intestine and of digestive glands. This shows that the concentration of amyloclastic enzymes in the intestinal mucosa and liver would be maximum in *Cirrhina mrigala*, since these enzyme extracts digest 5 ml of 1 percent starch solution in the shortest time. In *Labeo rohita* and *Cirrhina mrigala*, although the intestinal bulb and liver show nearly the same concentration of amylase, the rest of the intestine is considerably more amyloclastic in *Labeo rohita* than in *Catla catla*, so that the overall amylase secreting capacity would be more in *Labeo rohita* than in *Catla catla*. These results correlate well with the data on the rate of passage of digestible plant matter.

The rate of passage of several animal foods was found to be fastest in *Catla catla*, slower in *Cirrhina mrigala*, and slowest in *Labeo rohita* (Table I). It can be seen from Table II that although the bile of *Catla catla* shows less proteolysis, its intestinal mucosa and liver are much more proteolytic than that of *Labeo rohita* and *Cirrhina mrigala*, so that the overall concentration of proteolytic enzymes would be maximum in *Catla catla*. The intestinal bulb and anterior half of intestine of *Labeo rohita* have a very weak concentration of proteolytic enzymes. Therefore, although the hind half of intestine and especially the liver show more proteolysis, the overall concentration of proteolytic enzymes is likely to be less in *Labeo rohita* than in *Cirrhina mrigala*. These results, therefore, correlate well with the data on the rate of passage of animal foods, described earlier. It is of great interest that these differences in the passage of animal foods are not marked, probably because the differences in the concentration of proteolytic enzymes are slight. This therefore furnishes another clear-cut instance of correlation between rate of food passage and efficiency of digestion.

5 DISCUSSION

When the data on rate of passage of different food items are cross-checked with the data on the concentration of different digestive enzymes, it is seen that the rate of food passage is related to the efficiency of digestion. Thus, food items biochemically so constituted as to be more amenable to the digestive enzymes of a particular species, passed out at a faster rate than others. This is probably correlated with the absence of cellulase, chitinase and other higher carbohydrases. Thus coarse plants and animal foods with thick chitinous exoskeleton, were retained for a longer time than others. Moreover, while the totally indigestible algae passed at a more or less similar rate in the intestine, the passage of digestible plant matter was fastest in Cirrhina mrigala and that of animal foods fastest in Catla catla, which showed maximum amyloclastic and proteolytic activities, respectively.

The relationship between the rate of food passage and the concentration of the digestive enzymes is of great significance in fish biology. It indicates that food items which pass rapidly through the intestine are more efficiently used, since rapid food passage is associated with high digestibility due to high concentration of the requisite enzymes. Moreover, a rapid food passage may also mean a similar increase in the rate of feeding.

A relationship of this kind has so far been sought only in farm mammals. Thus Ewing and Smith (1917) found that in the steer, a rapid passage was associated with high digestibility. Balch (1951) found that the ability to digest crude protein and ether extract fractions of hay and mangolds was greatest in cows that retained hay for the shortest time in the reticulo-rumen. He, however, found that variations in the digestibility of the crude fibre were not related to the rate of passage. Blaxter et al.(1956) obtained results supporting those of earlier workers. They found that those diets which are intrinsically highly digestible pass more rapidly through the guts of sheep.

Considering now the results of the present work in relation to 'major carp' culture, it may be suggested that the digestible plant matter would be utilized with maximum intensity by Cirrhina mrigala, less by Labeo rohita, and least by Catla catla, while the animal foods would be utilized most intensively by Catla catla, less by Cirrhina mrigala, and least by Labeo rohita. The difference in efficiency of utilization would, however, be considerably more marked in the case of plant matter than in the case of animal foods.

Several workers have determined the food of these species on the basis of examination of gut contents (Mookerjee, 1945; Mookerjee and Ghosh, 1945; Mookerjee and Das, 1945; Chacko and Kurian 1950-51; Begum, 1959; George, 1963). All these authors have shown that although these species ingest a variety of phytoplankters, zooplankters and higher aquatic plants, Catla catla prefers to feed on plankton, mainly zooplankton, while Labeo rohita and Cirrhina mrigala prefer to feed on plant matter, including decaying vegetation. The present investigation confirms that Catla catla can utilize animal food better than Cirrhina mrigala and Labeo rohita, and shows that the latter is less adapted for it than even Cirrhina mrigala. Utilization of plant matter, however, is considerably better in Cirrhina mrigala and Labeo rohita than in Catla catla. Thus it appears from the present work that Catla catla is a "planktivore" with a bias towards zooplankton, while Labeo rohita and Cirrhina mrigala are "herbivores".

Within the confines of their preferences, the comparative utility of different food items would depend upon their rate of digestibility, for example, Labeo rohita and Cirrhina mrigala, though both mainly "herbivores", do not utilize all plants equally. The fact that many fishes cannot digest certain algae is also already known (Fish, 1951; George, 1963). The present work while confirming this, has further shown that these indigestible items of food are retained for a longer time, nearly two days, in the intestine. It may, therefore, be stated that fishes living in ponds where such indigestible foods are abundant, may suffer a considerable loss of time and energy in having their guts full of these foods, resulting in retardation of their growth. This investigation has revealed that filamentous algae, such as Spirogyra and Ulolthrix, higher aquatic plants such as Lemna, decayed vegetation, and zooplankters such as Daphnia, Cyclops, Diaptomus, and the rotifer Brachionus, are more rapidly digested and would, therefore, be more intensively utilized, affording comparatively faster rate of growth.

6 ACKNOWLEDGEMENT

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7 REFERENCES

Ahsan-ul-Islam, 1949 The comparative histology of the alimentary tract of certain fresh water teleost fishes. Proc.Indian Acad.Sci.(B), 33:297-821

Balch, C.C., 1951 Factors affecting the utilization of food by dairy cows. Rate of passage of food through the digestive tract. Brit.J.Nutr., 4:4-361

Barrington, E.J.W., 1942 Gastric digestion in lower vertebrates. Biol.Rev., 17:1-27

___________, 1957 The alimentary canal and digestion. In The physiology of fishes ed. by M. Brown. New York, Academic press, pp. 109-61

Blaxter, K.L., N. McGraham and F.W. Wainmann, 1956 Some observations on the digestibility of food by sheep and on related problems. Brit.J.Nutr., 10:2-69

Begum, A., 1959 Observations of the food of major carps. Agric.Pakist., 10:539-54

Chacko, P.I. and G.K. Kurian, 1950-51 The bionomics of carp, Catla catla, in South Indian waters. Proc.zool.Soc.Lond., 120(1):31-42

Dobreff, M., 1927 Magenverdauung der Haifische: eine Bemerkung über die Hungerausdauer derselben Fische. Pflügers Arch.ges.Physiol., 217:221-34

Ewing, P.V. and F.H. Smith, 1917 A study of the rate of passage of food residues through the steer and its influence on digestion coefficients. J.Agric.Res., 10:2

Fish, G.R., 1951 Digestion in Tilapia esculanta. Nature, Lond., 167:901-2

George, M.G., 1963 Selective digestion in the major carps of India. Curr.Sci., 32:2-79

Hirao, S., J. Yamada and R. Kikuchi, 1960 On improving the efficiency of feed for fish culture. Transit and digestibility of diet in eel and rainbow trout, observed by use of P32. Bull.Tokai Fish.Res.Lab., 27:67-72

Karpevich, A.E. and E. Bokoff, 1937 The rate of digestion in marine fishes. Zool.Zh., 16:28-44

Kapoor, B.G., 1953 The histology of the alimentary canal of Catla catla, a herbivorous fish. Proc.Indian Sci.Congr., 40:209-10

Maltzan, Grafin von M., 1935 Zur Ernährungsbiologie und Physiologie des Karpfens. Zool.Zbl., 3(55):191-218

Menon, M. and H.G. Kewalramani, Studies on some physiological aspects of digestion in three
1959 species of elasmobranchs. Proc.Indian Acad.Sci. (B), 50(1):26-39

Molnar, G., and I. Tolg, Relation between water temperature and gastric digestion in large-
1962 mouth bass (*Micropterus salmoides*). J.Fish.Res.Bd Can., 19:1005-12

Mookerjee, H.K., Life history of some major carps of Bengal. Sci.and Cult., 10(9)
1945

Mookerjee, H.K. and B.K. Das, Gut of carnivorous and herbivorous fishes in relation to
1945 their food. Part 3. Proc.Indian Sci.Congr., 32:109 p

Mookerjee, H.K. and S.S. Ghosh, Food of major carps. Part 3. Proc.Indian Sci.Congr.,
1945 32:110-1

Sarbahi, D.S., The alimentary canal of *Labeo rohita* (Ham.). J.Asiat.Soc., 5:2-87
1940

Sokolov, N.P. and M.A. Chvaliova, Nutrition of *Gambusia affinis* on the rice fields of
1936 Turkestan. J.Anim.Ecol., 5:390

Sullivan, M.X., The physiology of the digestive tract of elasmobranchs. Bull.U.S.Bur.Fish.,
1907 (27):1-27

van Slyke, D.D. and F.G. White, Digestion of protein in the stomach and intestine of the
1911 dogfish. J.biol.Chem., 9:209-17

Vonk, H.J., The specificity and collaboration of digestive enzymes in Metazoa. Biol.Rev.,
1937 12:245-84

__________, Advances in enzymology. Nord and Werkman, eds., New York, Interscience, vol.1:
1941 371 p.

Weinland, E., Zur Magenverdauung der Haifische. 1 und 2. Z.Biol., 41:35-275
1901

Yonge, C.M., Evolution and adaptation in the digestive system of the Metazoa. Biol.Rev.,
1937 12:87-115

Yung, E., Recherche sur la digestion des poissons. Arch.Zool.exp.gén., 3:7-121
1899

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III-VIII/E-3

FEEDING OF EELS (ANGUILLA ANGUILLA) IN PONDS

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Abstract

It is possible to feed elvers and eel fingerlings in ponds with minced fish and shrimps or fresh meat.

The food quotient for elvers is lower than 10 and for fingerlings also it may be about the same.

The results of experiments described in this report show that commercial pond feeding of eels is feasible.

L'ALIMENTATION DES ANGUILLES (ANGUILLA ANGUILLA) EN ETANG

Résumé

On peut nourrir les civelles et les jeunes anguilles en étang avec du poisson et des crevettes hâchés ou de la viande fraîche.

Le quotient alimentaire des civelles est inférieur à 10 et il en est probablement de même pour les jeunes anguilles (fingerlings). Les résultats des expériences décrites dans cette communication montrent que l'alimentation commerciale des anguilles en étang est réalisable.

III-VIII/E-3

ALIMENTACION DE ANGUILAS (ANGUILLA ANGUILLA) EN ESTANQUES

Extracto

Es posible alimentar angulas y alevines de anguila en estanques con pescado y mariscos o carne fresca picados.

Los cocientes de alimentos para las angulas es menor de 10, y también para los alevines puede que sea aproximadamente el mismo. Los resultados de los experimentos descritos en este informe muestran que es factible la alimentación comercial de las anguilas en estanques.

Feeding experiments with elvers and small eels (fingerlings) (Anguilla anguilla) in ponds were made by the Institut für Küsten- und Binnenfischerei, Hamburg, in the years 1963-1965, to determine whether and under what conditions pond culture of eels is possible. A short paper about the results known so far has already been published (Koops, 1965).

1 GROWTH OF ELVERS IN PONDS

An analysis of the growth of elvers in ponds is of some interest for several reasons. Elvers are the cheapest stocking material for eels (price for elvers in Germany is 0.01 - 0.02 DM each). Since the growth rate of individual eels differs greatly from the economic point of view the stocking of elvers permits sorting out the faster growing specimens for further feeding. Lastly, it is possible to learn more about the sexual development of the eel. Japanese investigations on Anguilla japonica have shown that the percentage of females in the total stock is 50-60 percent in natural waters, but only 0.5 - 9 percent in pond culture (Matsui, 1952). In the case of the European eel, some observations indicate that in most of the elvers the sex ratio is not constant.

For investigations on the growth of elvers, in May 1963, one 100 m^2 pond in Gorleben/Elbe was stocked with 3 kg (= 7,500) elvers (experiment 1). Because of unfavourable conditions (renewal of water was not possible) the results obtained at harvest on the growth rate represent minimum values.

Food was given in the form of minced coarse fish on a gauze frame. For control measurements samples of eels were taken at the feeding place. However it was revealed at the end of the experiment that the average weights of eels, as estimated from these samples were too high, and so these samples have to be considered as considerably biased (Table I).

Table I

The growth of elvers as determined in a pond experiment at Gorleben/Elbe

Date	No.	Length in mm			Weight in g			k factor
		min.	average	max.	min.	average	max.	average
15- 5-63	58	68	77	83	0.26	0.40	0.46	0.0800
4-10-63	48	86	112	140	0.64	1.77	3.61	0.1196
29- 5-64	49	83	116	143	0.50	2.20	4.04	0.1320
10- 6-64	67	87	122	176	0.74	3.05	10.41	0.1522
11- 8-64	337	104	145	211	1.34	5.24	16.94	0.1601
9-10-64	39	107	167	245	1.71	7.80	26.10	0.1518
Total autumn 64	5151	78	136	307	0.50	4.20	57.66	-

(k factor - condition factor, $k = \frac{100G}{L^3}$; G = weight in g; L = Length in cm)

It is obvious that the k factor increases with increasing length of the eels. Table I shows further by how much the growth rate of eels differs. From May, 1963 until autumn 1964 the weight of slowest growing eels had at least doubled. Average weight had increased by ten times and a few eels weighed 120 times that at the beginning. In an aquarium experiment (experiment 2) the difference of growth was similar, but did not vary so much. Probably the insufficient feeding of the elvers is the reason for the high growth difference in the pond. For culturing eels in a pond several sortings into size-groups will be necessary. Table II shows the size composition of the total pond stock in autumn 1964, compared with the size composition of elvers kept and fed in the aquarium during the same period.

Table II

Size composition of elvers reared and fed for two summers in a pond and in an aquarium

Length in cm	Weight in g	Pond (n=4958) percent	Aquarium (n=79) percent
7 - 10	0.5 - 1.5	7	4
11 - 15	2.1 - 5.6	78	46
16 - 20	6.9 - 13.7	13	46
21 - 25	15.6 - 27.0	1	5
26 - 30	30.0 - 57.7	1	0

The average weight of cultured eels - the k factor increases from 0.1200 in eels of 10 cm to ca. 0.1700 in eels of 20 cm - is considerably higher than the weight of eels of comparable size living in natural waters. The food-quotient could not be determined in the pond experiment. In the aquarium experiment, it was between 5 and 10, for water temperatures from 14-20°C. The total mortality in the pond experiment was 31 percent from May 1963 to autumn 1964. The total weight of the eels stocked increased from 3 kg at the time of stocking to 20.8 kg at the time of fishing.

2 GROWTH OF EEL FINGERLINGS IN PONDS

Small eels from 15 - 35 cm are referred to as "fingerlings" here, and they are caught in the tidal area of the river Elbe and other rivers for stocking inland waters. Unlike elvers these eels belong to several age groups. The percentage of males is higher (up to 80 percent). Males are slow-growing (maximum length about 42 cm) and therefore undesirable for pond culture.

2.1 First feeding experiment

In May 1964 a 100 m^2 pond in Gorleben/Elbe was stocked with 210 kg (= 15,000) eel fingerlings (average weight 13.6 g).

The pond was supplied with ground water of 9°C and the temperature in the pond did not exceed 16°C. The renewal of water was limited to about 1 litre per second. The quantity of food differed and depended on the quantity of coarse fish caught in the nearby river fishery. On an average it was not possible to feed more than 30 percent of the quantity needed. In general, at a maximum more than 10 percent of the total weight of the eels were fed.

At the time of stocking the eels were extremely lean and the average weight was only two-thirds of the weight normally to be expected. About 15 percent of the eels suffered from the "cauliflower" 1/ disease and in the first six weeks there was a loss of 12 percent by the "red disease" 2/.

Since the eels hide in the substratum, special "Eternit" plates of 1 m^2 size were placed on stones at the bottom of the pond. A 1 m^2 plate is sufficient as a hiding place for 25 kg of eels.

Minced coarse fish were used as feed. Apart from the coarse fish obtained from the river fishery, deep frozen sea fish and shrimps and slaughter house refuse were also used. The pond was rectangular in shape. A long and narrow pond has been found best suited

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1/ Ulcers resembling cauliflower in appearance on the jaws and nostrils and occasionally on the fins and other parts of the body.

2/ Highly infectious bacterial disease caused by Pseudomonas punctata forma Sacrowiensis, resulting in red colouration of the body and fins.

for feeding eels because the eel when searching for food orientates by its sense of smell. So the current of water inside the pond aids the eel to detect the food. The feed was given on a gauze frame in order to be able to remove feed residues, such as scales and bones. The data on the growth of the fingerlings is given in Table III.

Table III

The growth of eel fingerlings in a pond

Date	Length min.	Length average	Length max.	Weight min.	Weight average	Weight max.	k factor average
8- 5-64	15	22.2	31	4.2	13.6	36.5	0.1094
8- 7-64	17	23.7	33	0.7	19.1	48.5	0.1363
3-11-64	16	25.5	37	4.7	27.0	108.3	0.1471
7- 7-65	17	26.6	37	5.3	33.4	109.5	0.1665

The average weight doubled between May 1964 and November 1964. However, it must be stressed that the growth rate could only be followed by taking sub-samples. The pond had not been fished out completely, and the bias of sampling which has entered these calculations cannot be estimated. Another experiment (experiment 4) carried out at Müden/Mosel has shown that here the average weight calculated from the sub-samples was lower than the overall average weight.

In the Gorleben experiment the increase of the k factor was found to be higher than normally expected, for at the beginning the eels were extremely lean. Table IV demonstrates to what extent the k factor can rise in such a case. In the table the data on two control samples collected on 12 August 1964, three months after stocking, and on 2 July 1965, 14 months after stocking, are compared.

Table IV

Increase of the k factors in the course of experiment 3

Size group cm	n	12-8-64 average k	n	2-7-65 average k
16 - 20	42	0.1300	6	0.1507
21 - 25	50	0.1319	52	0.1555
26 - 30	34	0.1387	49	0.1682
31 - 35	9	0.1503	41	0.1777
36 - 40	-	-	4	0.2029

It can also be concluded that the k factor of fingerlings increases with length. Eels with "cauliflower" disease were lower in weight than healthy eels and the condition factor decreased with increase in this disease.

In aquarium tests it has been proved that the "cauliflower" grows relatively quickly in fresh water. Such eels are hindered very much in taking food and finally may die. The aquarium tests showed also that new tumours appeared on eels which at first seemed to be free from "cauliflower"; an increase of the infection rate also could be observed in the pond experiment.

2.2 Second feeding experiment

On 30 April 1965, a pond of 700 m^2 at Müden/Mosel was stocked with 350 kg eel fingerlings with an average weight of 16.6 g. This corresponds to a density of 30 eels per m^2. In this experiment 25 percent of the eels had the "cauliflower" disease at the time of stocking.

Similar to experiment 3 (Gorleben) the eels were fed with minced coarse fish. However there was not sufficient feed because of the poor results of the river fishery. Only about 20-25 percent of the needed feed was available. The result of the total fishing on 25 October 1965, six months after stocking, was:

15,570	small eels	=	428.5 kg	average weight	27.5 g
1,012	medium eels	=	79.5 kg	average weight	78.6 g
68	silver eels	=	5.5 kg	average weight	80.9 g
16,650	total	=	513.5 kg	average weight	30.8 g

This experiment permitted the calculation of the food quotient (total quantity of food supplied divided by the difference between the total weight of eels at the commencement and the end of the experiment) for eel fingerlings. This amounted to 14.5. Because of the small quantities of feed supplied, the food quotient is relatively high, since a considerable portion of it was necessary for maintenance and only a small amount was available for further growth.

Another factor responsible for the high food quotient is the high mortality (some 25 percent) as caused mainly by the diseases observed. It is likely that the food quotient will be lower than 10 if more feed can be supplied and if the natural mortality could be considerably lowered. Sorting out of diseased eels prior to stocking is highly recommended.

3 REFERENCES

Koops, H., 1965 Fütterung von Aalen in Teichen. Arch.FischWiss., 16(1):33-8

Matsui, I., 1952 Studies on the morphology, ecology and pond culture of the Japanese eel (*Anguilla japonica* Temminck and Schlegel). J.Shimonoseki Coll.Fish., 2(2):1-245

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EVALUATION OF THE RELATIVE SUITABILITY OF VARIOUS GROUPS OF ALGAE AS FOOD OF MILKFISH IN BRACKISH-WATER PONDS

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III/E-4

EVALUATION OF THE RELATIVE SUITABILITY OF VARIOUS GROUPS OF ALGAE AS FOOD OF MILKFISH IN BRACKISH-WATER PONDS

Abstract

An evaluation of the relative suitability of the four major groups of brackish-water pond algae as milkfish food was made by digestion experiments, observations on their suitability as food and effect on proper pond management.

The nutritive ratios of fresh *Chaetomorpha*, phytoflagellates, filamentous blue-greens and diatoms are 1:33.44, 1:2.47, 1:1.18 and 1:1.54 respectively. The *Chaetomorpha*-produced detritus has been found to have a nutritive ratio of 1:1.66.

Fresh *Chaetomorpha* is undesirable because the milkfish under harvestable sizes are unable to consume it due to its coarseness and fibrous nature and it interferes with the manipulation of pond fish populations. *Chaetomorpha*-produced detritus can serve as food for large-sized milkfish also.

A bloom of phytoflagellates is harmful to milkfish as it reduces the schooling and grazing activities by obstruction of vision, reduces light penetration and causes oxygen depletion as a result of the decomposition of dead organisms.

Filamentous blue-greens and benthic diatoms that grow on pond bottoms are the most desirable food for all age groups of milkfish. A luxuriant growth of these algae on pond bottom can crowd out undesirable algae and possibly other harmful organisms in the ponds and create better environmental conditions for the fish.

EVALUATION DES AVANTAGES RESPECTIFS DE DIVERS GROUPES D'ALGUES EN TANT QU'ALIMENT POUR LES CHANOS ELEVES EN ETANGS A EAUX SAUMATRES

Résumé

Les avantages respectifs des quatre principaux groupes d'algues croissant dans les étangs à eaux saumâtres en tant qu'aliment pour les *Chanos* ont été évalués à l'aide d'expériences portant sur leur digestibilité, et d'observations relatives à leurs qualités alimentaires et à leur effet sur l'aménagement rationnel des étangs.

La valeur nutritive des *Chaetomorpha*, des phytoflagellés, des algues bleues filamenteuses et des diatomées consommés à l'état frais est respectivement de 1:33,44, 1:2,47, 1:1,18 et 1:1,54. Il a été constaté que les détritus provenant de *Chaetomorpha* ont une valeur nutritive de 1:1,66.

A l'état frais, les *Chaetomorpha* sont à déconseiller car les *Chanos* au-dessous de la taille exploitable ne sont pas capables de s'en nourrir en raison de leur consistance grossière et fibreuse; en outre elles gênent les manipulations de poissons en étang. Les détritus de *Chaetomorpha* peuvent servir également d'aliment pour les *Chanos* de forte taille.

Une surabondance de phytoflagellés est nuisible aux *Chanos* car elle gêne l'agrégation et le brout en diminuant la visibilité, elle s'oppose à la pénétration de la lumière et abaisse la teneur en oxygène de l'eau par suite de la décomposition des organismes morts.

Les algues bleues filamenteuses et les diatomées benthiques qui croissent sur le fond des étangs constituent les aliments les plus appropriés aux *Chanos* de tous les groupes d'âge. Lorsque ces algues se développent abondamment sur le fond d'un étang, elles peuvent conduire à l'élimination des autres algues indésirables et éventuellement des autres organismes nuisibles, créant ainsi de meilleures conditions de milieu pour les poissons.

EVALUACION DE LA CONVENIENCIA RELATIVA DE VARIOS GRUPOS DE ALGAS COMO ALIMENTO DEL SABALOTE CHANOS CHANOS EN ESTANQUES DE AGUA SALOBRE

Extracto

Se efectuó una evaluación de la conveniencia relativa de los cuatro principales grupos de algas de estanques de agua salobre como alimento para el sabalote (Chanos chanos) mediante experimentos de digestión, observaciones sobre su utilidad como alimento y sus efectos sobre una adecuada explotación racional de los estanques.

Los coeficientes nutritivos de Chaetomorpha fresca, fitoflagelados, algas filamentosas verde-azules y diatomeas son 1:33,44, 1:2,47, 1:1,18 y 1:1,54, respectivamente. Se ha comprobado que los detritos producidos por Chaetomorpha tienen un coeficiente nutritivo de 1:1,66.

Chaetomorpha fresca no resulta apropiada ya que el sabalote (Chanos chanos) inferior a tallas recolectables no puede consumirlo debido a la dureza y carácter fibroso de aquélla y a que dificulta la manipulación de las poblaciones de peces de los estanques. Los detritos producidos por Chaetomorpha pueden servir como alimentos también para el sabalote de tamaño grande.

Una floración de fitoflageladas es perjudicial para el sabalote ya que reduce las actividades gregarias y de alimentación de éste por obstrucción de la visión, disminuye la penetración de la luz y determina una desoxigenación como resultado de la descomposición de organismos muertos.

Las algas verde-azules filamentosas y las diatomeas bentónicas que crecen en el fondo de los estanques son el alimento más conveniente para todos los grupos de edad del sabalote. Un crecimiento exuberante de estas algas en el fondo de los estanques puede sofocar el desarrollo de algas inadecuadas y posiblemente de otros organismos dañinos en los estanques y crear mejores condiciones ambientales para los peces.

1 INTRODUCTION

The brackish-water ponds for the culture of milkfish, Chanos chanos (Forskal) in the countries of Indonesia, the Philippines and Taiwan, are distributed on the alluvial tidal flats of geologically recent deposits. The soil and the water of these flats are extremely rich because the streams running down from hinterland erode and bring down large amounts of plant nutrients, which are deposited together with the alluvium in this area. In the tropical climate, there are various groups of algae that can produce luxuriant blooms under these conditions. Some of these algae are very good for milkfish growth and advantageous for pond production. There are, however, also many kinds of algae that are undesirable for milkfish culture, either because they are unsuitable as food for milkfish, or because of some ill-effects of the algae on fish life and on the management of the ponds. Therefore, an intensive study of the relative suitability of the major groups of algae that are commonly produced in brackish-water ponds as food for milkfish, is one of the requirements for the improvement of this type of fish culture.

2 THE DOMINANT GROUPS OF ALGAE IN BRACKISH-WATER PONDS

The algae produced in brackish-water ponds can be grouped into four major groups: the green, Chlorophyceae; the diatoms, Bacillariophyceae; the blue-greens, Cyanophyceae; and the various free-living phytoflagellates. The dominant genera of the Chlorophyceae are Chaetomorpha and Enteromorpha, but the latter genus is very rare; of the Bacillariophyceae Navicula, Pleurosigma, Mastogloia, Stauroneis, Amphora, Nitzschia and various unidentified genera; of the Cyanophyceae Oscillatoria, Lyngbya, Phormidium, Spirulina, Microcoleus and possibly other genera of the order Oscillatoriales; and of the free-living phytoflagellates Chlamydomonas, Pyramimonas, Chlorosarcina, Gymnodinium, Chilomonas, and a number of unidentified flagellates.

3 THE RELATIVE DIGESTIBILITY OF VARIOUS GROUPS OF ALGAE

Determination of the amount of digestible nutrient that a particular food supplies to the fish is the simplest, but the most important method of measuring the relative values of foods. A number of digestion experiments were made with the four major groups of algae for milkfish of three different sizes, fingerlings (3 to 5 g), juveniles (15 to 20 g), and half-grown fish (60 to 100 g) which are commonly used for stocking ponds in Taiwan. For these experiments a series of concrete ponds of identical size, 6 x 4 x 0.5 m were used. Each digestion experiment was made over a five-day period. Feeds of these four groups of algae were given daily at the rate of 20 to 25 percent of the total body weight of the fish stocked in the pond. The algae of both fresh and detrital forms were given on the basis of wet weight, which includes approximately 88 to 93 percent of water. During the experiments, the faeces excreted by each group of test fish were carefully collected with a glass tube by suction. The total weight of each kind of food consumed, and the total amount of faeces excreted during the experiments were measured. The chemical compositions of different feeds and the organic nutrients in the faeces[1] from different feeding trials were determined. The digestion coefficients of protein, fat, nitrogen-free extract and fibre, the percentage of digestible protein, the percentage of total organic digestible nutrients and the nutritive ratio of each kind of food were also computed, and are given in Table I.

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[1] It may be noted that the residual organic nutrients in the faeces of the fish might lose some portion into the water, and this loss might vary with the different species of fish and with different kinds of food. However, the faeces of milkfish remain in compact clots after they are excreted, so the results as indicated appear satisfactory for the purpose of this study.

Table I

Composition of four major groups of algae and their relative nutritive value as milkfish food
(The water temperature during digestion experiments ranged from 29° to 33°C and the salinity from 24 to 27 ppt)

Group of algae	Number of samples	Total Composition						Digestive coefficient[1]				Digestible[2] protein (%)	Total digestible nutrients[3] (%)	Nutritive[4] ratio
		Total dry matter (%)	Crude protein (%)	Crude fat (%)	Nitrogen-free extract (%)	Fibre (%)	Mineral matter (%)	Crude protein (%)	Crude fat (%)	Nitrogen-free extract (%)	Fibre (%)			
Chaetomorpha														
Fresh form	15	8.54:	2.82	0.91	1.50	1.22	2.09	3	72	87	21	0.09	3.12	1 33.44
Detrital form	15	10.72:	3.46	0.38	3.21	0.98	2.69	66	89	85	37	2.28	6.13	1 1.66
Phytoflagellates[5]														
Fresh form	5	11.98:	3.91	1.32	5.61	0.42	0.72	81	91	78	23	3.17	10.41	1 2.37
Diatoms[6]														
Fresh form	15	12.87:	2.89	0.94	2.25	0.27	6.52	87	96	84	19	2.51	6.48	1 1.54
Filamentous blue-green algae[7]														
Fresh form	15	9.86:	2.32	0.21	1.52	0.70	5.11	69	86	81	38	1.60	3.49	1 1.18

[1] Digestive coefficient: $\frac{\text{The amount of a class of organic nutrient in the feed.The amount of that class of organic nutrient in faeces}}{\text{The amount of that class of organic nutrient in the food}} \times 100$

[2] Digestible protein: The percentage of protein in the food x Digestion coefficient of protein

[3] Total digestible nutrients: The sum of digestible protein, fibre, nitrogen-free extract and fat x 2.25

[4] Nutritive ratio: $\frac{\text{The percentage of total digestible organic nutrients - The percentage of digestible protein}}{\text{The percentage of digestible protein}}$

[5] Centrifuged from the pond water where Chlamydomonas and Chilomonas flagellates bloomed predominantly.

[6] Furnished as the diatom sludge

[7] Collected from the pond bottom where the dominant genera, Oscillatoria and Lyngbya grew

3.1 Filamentous green algae

Although fresh Chaetomorpha contains a relatively high percentage of crude protein, the proportion digested by milkfish of the above-mentioned sizes is extremely low, computed at 0.09 percent, and it has a high nutritive ratio of 1:33.44. Since it is only the digestible protein which supplies the necessary protein for increase in body weight, this kind of feed is apparently unsuitable for growing milkfish. However, Chaetomorpha can be used as feed of relatively high value for milkfish when it dies and on decomposition, its protein content becomes digestible for milkfish. The digestion experiment showed that the Chaetomorpha-produced detritus supplies 2.28 percent digestible protein, and with a relatively low nutritive ratio of 1:1.66 for milkfish.

3.2 Phytoflagellates

The phytoflagellates used for this digestion experiment were mostly Chlamydomonas and Chilomonas. These organisms were obtained by centrifuging the water where they had bloomed. This experiment showed that the phytoflagellates are the most nutritious feeds for the milkfish as they supply 3.17 percent digestible protein and 10.41 percent (including fat x 2.25) total digestible nutrients and with a nutritive ratio of 1:2.37.

3.3 Diatoms

The diatoms sludge, formed by various species of bottom-dwelling diatoms, was used for this digestion experiment. The results indicated that the diatoms are undoubtedly a nutritious food for milkfish as the diatom cells contain a high portion of digestible organic nutrients for the fish.

3.4 Filamentous blue-green algae

The filamentous blue-greens used for this experiment comprised mainly various species of the family Oscillatoriaceae. This group of algae, as shown in the results of this experiment, is valuable as food for milkfish. They furnish 1.60 percent digestible protein and have a low nutritive ratio of 1:1.18.

4 THE RELATIVE DESIRABILITY OF VARIOUS GROUPS OF ALGAE

4.1 Food and the feeding mechanism of milkfish

It is believed by some fisheries biologists that milkfish are plankton feeders. However, milkfish gill rakers are not very well adapted to filter planktonic algae from the water. Feeding experiments conducted in concrete ponds indicated that milkfish have little food in their stomachs when they were stocked in ponds containing large quantities of phytoflagellates. This was also found to be the case for fish from plankton-rich earth ponds. With the exception of the planktonic algae that die and accumulate on the pond bottom, the quantity of fresh plankton taken as food by milkfish in ponds is negligible, even by milkfish fingerlings.

Diatoms are found in both planktonic and benthic forms in brackish-water ponds. Very common planktonic genera include Synedra and Melosira. These were found whenever the pond water was examined, but they never grow so abundantly as to make the pond water turbid, as did the phytoflagellates. The benthic diatoms, such as the Navicula, Pleurosigma, Mastogloia, Stauroneis, etc., together with the various species of filamentous blue-green algae, form the algal pasture on the substratum. Since milkfish of various growth stages suck up foodstuffs from the pond bottom, these pasture algae furnish the most suitable forms of milkfish food.

Milkfish of various sizes often feed on the algal scum floating on the water surface, but show no special preference for food from the upper layers of the water.

4.2 Palatability

The palatability of food is of great importance in feeding fish for high production. Unless the food is palatable, milkfish will not eat enough to increase their body weight efficiently. It also seems probable that well-liked foods are even digested somewhat better than those which are equally nutritious, but less palatable. Schuster (1960) states that the milkfish either in the sea or in ponds resort to facultative feeding. However, there is evidence that the palatability of food to milkfish in ponds varies greatly with the different kinds and groups, and different growth stages and conditions of the algae, and also with the different growth stages of the milkfish itself.

Experiments conducted in concrete ponds show that milkfish usually have empty stomachs and lose weight when they are exclusively fed with fresh Chaetomorpha. Milkfish below harvestable size are unable to eat this coarse, fibrous alga. Chaetomorpha-produced detritus can serve as food for relatively large milkfish, but it seems to be less palatable than those algae which are fresh, tender and soft.

Observations made in both concrete and large excavated ponds indicate that the fresh filamentous blue-greens and the diatoms are the most palatable groups of algae produced in the brackish-water ponds. Probably due to their softness and tenderness, these algae are preferred by milkfish of all growth stages, including larval fish.

Feeding experiments with milkfish of various sizes show that the detritus produced from the diatoms is more palatable than that formed by any other group of algae. However, milkfish also like the detritus produced from filamentous blue-greens and from phytoflagellates, with no particular preference for either one. But even large milkfish dislike Chaetomorpha-produced detritus.

5 THE RELATIVE DESIRABILITY OF VARIOUS GROUPS OF ALGAE FOR POND MANAGEMENT

Dense growth of Chaetomorpha as a submerged weed interferes with the movements of the milkfish and limits the holding capacity for fish stocks in ponds. Moreover, these obnoxious algae interfere with the harvest of fish from ponds with gill nets or draining of the pond water. Periodical thinning of the fish population, by selective gill netting of the larger fish, is one of the most important ways of manipulating the population for increased production. So, despite its nutritive values as feed, Chaetomorpha is not desirable in milkfish ponds.

Milkfish growth ceases when a bloom of free-living phytoflagellates occurs in the pond. These algae may obstruct the grazing activities of the fish by blinding them. Furthermore, such a bloom obstructs the penetration of sunlight and the dense shading hinders the growth of the desirable filamentous blue-greens and benthic diatoms on the pond bottom. It has also been found that the death of the phytoflagellates following a heavy bloom often causes a high mortality of the fish due to depletion of the dissolved oxygen in the pond water. Thus the phytoflagellates as a group are harmful for the management of milkfish ponds, and they give the fish farmers a great deal of trouble.

Besides supplying the most palatable and nutritious food, the filamentous blue-greens and the benthic diatoms forming the pasture algae facilitate pond management and furnish the milkfish with better environment. A luxuriant growth of the pasture algae can crowd out the undesirable and harmful algae by minimizing the amounts of plant nutrients available to them. Snails that compete with milkfish for food can also be crowded out from ponds by a dense covering of the stratum with algal pasture. Milkfish appear lively, schooling round the pond, and actively grazing on the fresh, tender and soft pasture algae in clear pond water. This favourable environment, however, can develop only when these pasture algae thrive luxuriantly on the floor of the pond. Therefore, good growth of algal pasture is essential for the accelerated growth of the milkfish.

6 REFERENCE

Schuster, W.H., Synopsis of biological data on milkfish, _Chanos chanos_ (Forskal) 1775.
1960 _FAO Fish.Biol.Synops._, (4) : pag.var.

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ON A NEW ARTIFICIAL FEED FOR CARP FRY

by

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Abstract

A series of laboratory experiments on rearing of carp fry from hatchling to 15-day old fry were conducted using 19 cheap and easily available items of feed. Besides individual items, the promising items of feed were prepared into combinations of two, three, four and five and in different ratios. Survival and growth of fry were taken as the criteria for determining the relative value of the various items of food.

The data were statistically analyzed in detail comparing the results of all experiments and the conclusion was drawn that a mixture of notonectids (insects), small prawn and cow-pea in the ratio of 5:3:2 yielded most satisfactory results. Any other ratio of the three items did not show comparable result.

The advantages of using the aquatic insect and prawn populations and comparative economy of the supplementary feed are discussed.

Field experiments conclusively proved the feed to be effective for all species of cultivated carps, in giving better production of healthy and well grown fry. The feed appears to satisfy all the essential requirements for commercial use. The mixture of oil cake and rice bran which is the commonly used feed in India, has been found to be less effective.

UN NOUVEL ALIMENT ARTIFICIEL POUR LES ALEVINS DE CARPE

Résumé

Dans une série d'expériences en laboratoire, des alevins de carpe ont été élevés depuis l'éclosion jusqu'à l'âge de 15 jours avec une nourriture artificielle comportant 19 types d'aliments faciles à obtenir et peu coûteux. Ces aliments ont été utilisés isolément ou en rations composées comprenant jusqu'à 5 aliments différents. Les taux de survie et de croissance des alevins ont servi de critères pour apprécier la valeur relative des divers types d'aliments.

En procédant à une analyse statistique détaillée et comparative des données fournies par toutes les expériences, on en est arrivé à la conclusion que les meilleurs résultats étaient obtenus avec un mélange de notonectes (insectes), de petites crevettes et de dolics dans la proportion 5:3:2. Aucune autre formule de mélange de ces trois aliments n'a donné des résultats comparables.

Les auteurs examinent les avantages qu'il y a à utiliser les insectes aquatiques et les crevettes ainsi que l'économie relative de l'alimentation d'appoint.

Des expériences en étang ont nettement démontré qu'avec toutes les espèces de carpes d'élevage, cette formule alimentaire permettait d'obtenir une production améliorée d'alevins sains et bien développés. Cet aliment paraît répondre à toutes les exigences d'une utilisation commerciale. Le mélange de tourteaux d'oléagineux et de son de riz qui est l'aliment artificiel le plus répandu en Inde, donne de moins bons résultats.

NUEVA ALIMENTACIÓN ARTIFICIAL PARA LOS JARAMUGOS DE CARPAS

Extracto

Empleando 19 clases de alimentos baratos y fáciles de obtener, se realizaron una serie de experimentos de laboratorio sobre la cría de jaramugos de carpa desde la fase de alevín recién eclosionado hasta la de jaramugos de 15 días. Además de los distintos tipos de alimentos aislados, se prepararon otros que podrían ser eficaces preparados combinando dos, tres, cuatro y cinco de ellos se adoptaron como criterio para determinar el valor relativo de los distintos productos alimenticios.

Se analizaron estadísticamente los datos con todo detalle, comparando los resultados de todos los experimentos y se llegó a la conclusión de que una mezcla de notonéctidos (insectos), camarones pequeños y caupí en la proporción 5:3:2 daba los resultados más satisfactorios. Cualquier otra proporción de los tres alimentos no dió resultados parecidos.

Se examinan las ventajas de emplear el insecto acuático y las poblaciones de camarones y la economía de la alimentación suplementaria.

Los experimentos de campo demostraron de un modo concluyente que la alimentación servía para todas las clases de carpas cultivadas, dando una mejor producción de jaramugos sanos y bien desarrollados. La alimentación parece que satisface todas las necesidades esenciales para poder usarla en escala comercial. Se ha visto que la menos eficaz es la mezcla de tortas oleaginosas y salvado de arroz, que es el alimento generalmente empleado en la India.

1 INTRODUCTION

Though fish cultural practices are in vogue all over India, the matter of artificial feeding of fish to get enhanced production does not appear to have received the attention it deserves. A review of available literature on this aspect of fish culture seems to indicate that almost all the work done has been concentrated on feeding the fry at the hatchery or nursery stage. Thereafter, availability of food for the growing fry, fingerlings and yearlings is left to the natural food production of the waters.

The obvious reasons for this omission of artificial feeding appear to be the consideration of economy in undertaking this operation in larger waters, as well as lack of sufficient information on suitable supplementary feeds for the various cultured fishes. However, fish culturists such as those in Japan (Kawamoto, 1957) who supplied supplementary diet in one form or another for rearing their stock of fish and obtained high production have sufficiently justified the usefulness of artificial feed in enhancing fish production.

The common items of feed used in India in nursery and rearing ponds are various types of oil cakes mixed with rice bran. With the recent initiation of intensive fish culture programs in the various States of India, it was felt necessary to develop a more suitable and balanced diet for cultured fish. With this in view, preliminary work commenced in this Research Institute, the main aim of which was to enhance fish production within a minimum rearing period. While the present work is limited to the observations on survival and growth of fish at the fry stage, it is proposed to continue the investigations to evolve suitable, cheap and effective artificial feed for fingerlings as well as for adult fish.

While taking note of the inherent handicaps involved in feeding fish, the authors feel that along with the development of a suitable feed, it may be necessary to evolve and improve the feeding technique in order to derive maximum benefits from artificial feeding. Though work on artificial feeding has been carried out by many other workers, emphasis has been on finding out the vitamin, mineral and other food requirements. The present work is mainly concerned with evolving a practical nursery diet for the fry of Indian carps.

2 MATERIAL AND METHODS

The experiments were conducted in 10-litre glass jars with equal quantities of tap water; this eliminated the possibility of introducing extraneous food items. The same number of hatchlings of *Cyprinus carpio* or *Labeo rohita* of the same parentage were introduced into each jar. Fry were reared for 15 days, feeding them with uniform quantities by volume of the various feed items, no attempt being made to determine the optimum requirements. The numbers of replicates were increased from two in early screenings to six in later experiments, since less effective feeds were eliminated with the progress of the experiments. Water in all the jars was partially replaced once in three days with fresh tap water, after cleaning and removal of accumulated unused feed and excreta. All fry were fixed in formalin on the sixteenth day for growth and survival rate analysis. Controls without feed yielded the same negative results in the first five sets of experiments, and were therefore not repeated.

Advantage was taken of the experience of earlier workers like Schäperclaus (1933), Alikunhi (1952), Alikunhi *et al.* (1954; 1955) and many others, who had established zooplankton as the main natural food of carp fry, and hence all items of feed were compared with this standard food. Growth and survival in individual jars were taken as the criteria for deciding the comparative merit of the different items of feed.

Uniformity was maintained in initial feeding (Palmer et al., 1951) and fry were fed from the third day after hatching. Consistency and availability of feed as possible factors affecting growth (Wolf, 1951b) were also taken into consideration. Feeding frequency was limited to once a day, though opinions differ on this issue (Palmer, loc.cit.). While the efficiency of each item was tested independently, no attempt was made to improve this efficiency in combination with any nutritionally inert or binding material.

The more important items including zooplankton were analyzed chemically to determine their protein, carbohydrate, fat and ash contents. Vitamin assay had, however, to be omitted for lack of laboratory facilities.

Selection of feed items was made taking into consideration: (i) economy, (ii) availability, (iii) ease of processing, (iv) keeping quality, (v) non-disintegrating and non-soluble nature, and (vi) consistency. The various items were first sun-dried thoroughly and thereafter powdered by hand or with a mortar and pestle. The powder was sieved through a fine mesh wire netting and kept in air-tight containers.

After the preliminary testing of individual items, poorer feeds were eliminated and the more promising items were tested in combinations of two, three, four and five by repeating the experiments. The particular mixtures were also prepared in different ratios of the constituent items.

The data collected from the fry reared in 195 jars were statistically processed to determine the comparative merit of each item and combination of items.

3 EXPERIMENTS AND OBSERVATIONS

Feeding experiments were carried out both in the laboratory and field during the years 1964 and 1965 with various items of feed singly or in combinations.

3.1 Single items

Nineteen items, viz. jowar (*Sorghum vulgare*), ragi (*Eleusine coracana*), Italian millet (*Setaria italica*), cow pea (*Vigna catjang*), Bengal gram (*Cicer arietinum*), horse gram (*Dolichos biflorus*), maize (*Zea mays*), cotton-seed (*Gossypium herbaceum*), duck weed (*Lemna minor*), mustard oil cake, rice bran, wheat bran, notonectids (*Anisops* sp.), fish roe, prawn (*Macrobrachium lamarrei*), fat-free fish protein, fish protein with fat, hydrolyzed protein and poultry feed, were tested. Besides the above items, additions of common salt or yeast in very low percentages were also tried.

Since fry fed with zooplankton yielded the best results in all jars, the optimum growth and survival is based on these results. The average growth and survival were 16.63 mm and 94 percent respectively.

Out of the 19 items given above, the data on 16 items only were studied in detail, deleting rice bran, horse gram and hydrolyzed protein, which yielded very low survival with almost negligible growth. In the remaining observations, since the differences in growth and survival between feeds were quite distinct, further repetition of experiments was not considered necessary. However, in the case of treatments which were repeated, there was no significant difference in either growth or survival. Since hatchlings of uniform size and age were used, growth measurements taken for the analysis were the final measurements. Analysis of variance was performed to see whether the treatments differed significantly.

Table I

Analysis of variance in single item trials

Source of variation	d.f.	Sum of squares	Mean sum of squares	F	Table value	
					P=0.05	P=0.01
Between sample means:	15	756.01	50.4006	99.29	1.67 (approx.)	2.04 (approx.)
Within samples:	432	219.27	0.5076			
Total:	447	975.28				

'F' is highly significant, which means that the samples differ significantly. But the value of 'F' gives only an overall significance and does not indicate the individual differences. Hence, for studying the individual difference between the samples, 't' test was employed. The t value was 1.96 for significance at 0.05 level; i.e. difference between means = 1.96 x SE = 1.96 x 0.1905 = 0.3734 or say 0.4, for significance at 0.05 level. The smallest difference between any two sample means which is significant at 0.05 level is 0.4.

From Table II, it is clear that though the percentage of survival is relatively less in the case of fish roe, due to its comparatively high growth result, it tops in ranking. However, fish roe did not sufficiently satisfy some of the important selection qualities, viz. availability, economy and keeping quality, and had to be dropped.

Further combination experiments were undertaken deleting poultry feed, maize, jowar, cotton seed and Italian millet.

3.2 Two-item mixtures

Out of 25 combinations of two items tested, the results of two combinations, viz. mustard oil cake plus rice bran, and prawn plus fish roe, were found to be very poor. Deleting the above two, the results of 23 combinations were analyzed for ranking. The analysis of variance is as shown in Table III.

'F' is highly significant and so the samples differ significantly. By the application of the 't' test, the least difference between sample means which is significant at 0.05 level is found to be about 0.5.

The most striking feature of the results of the experiment with two-item mixtures has been the elimination of the prevailing popular artificial feed, viz. mixture of mustard oil cake with rice bran, as a comparatively inefficient feed. From Table IV it is clear that notonectids plus cow pea in the ratio of 2:3 ranks first whereas the same items in the ratio of 1:1 dropped to the thirteenth rank. In double mixtures, yeast appears nutritionally quite effective.

3.3 Three-item mixtures

Since the efficiency of notonectids, prawn and cow pea (NPC) had become apparent in early trials they were used mainly for the three item combinations. Out of 20 combinations in different ratios tested, data of 17 were studied in detail deleting three, viz. NPC in the ratios of 2:5:3, 7:10:3 and 9:9:2. The analysis of variance for the 17 combinations was as shown in Table V.

Table II

Results of experiments with single item feeds, arranged in the order of efficiency of the feeds

Feed item	Average growth (mm)	Survival (percent)
Fish roe	11.5	68.0
Notonectids	10.1	96.7
Prawn	9.6	93.3
Fat-free fish protein	8.8	90.0
Fish protein with fat	8.9	56.0
Cow pea	8.4	96.8
Bengal gram	8.4	84.0
Duck weed	8.3	48.0
Poultry feed	7.9	88.0
Wheat bran	7.8	46.6
Maize	7.5	86.0
Jowar	7.2	96.7
Cotton seed	7.2	58.0
Italian millet	6.9	93.3
Mustard oil cake	7.1	38.8
Ragi	6.2	100.0

Table III

Analysis of variance of the results of experiments with two-item feed mixtures

Source of variation	d.f.	Sum of squares	Mean sum of squares	F	Table value P=0.05	Table value P=0.01
Between sample means:	22	877.52	39.8873	43.35	1.53 (approx.)	1.81 (approx.)
Within samples:	667	613.70	0.9201			
Total:	689	1,491.22				

Table IV

Results of experiments with two-item feed mixtures arranged in the order of efficiency of the mixtures

	Ratio	Average growth (mm)	Survival (percent)
Notonectids + cow pea	2:3	11.7	86.0
Notonectids + yeast	4:1	11.7	84.0
Prawn + yeast	4:1	11.8	70.0
Prawn + cow pea	2:3	11.4	88.0
Rice bran + prawn	1:1	11.2	94.0
Prawn + Bengal gram	1:1	11.1	82.0
Prawn + cow pea	1:1	10.8	98.0
Notonectids + mustard oil cake	1:1	10.9	75.0
Prawn + ragi	1:1	10.5	82.0
Notonectids + duck weed	1:1	10.2	86.0
Notonectids + Bengal gram	1:1	9.9	92.0
Notonectids + wheat bran	1:1	9.8	98.0
Notonectids + cow pea	1:1	9.7	94.0
Notonectids + fish roe	1:1	9.8	58.0
Cow pea + yeast	4:1	9.4	92.0
Notonectids + ragi	1:1	9.4	84.0
Cow pea + fish roe	1:1	9.4	58.0
Prawn + wheat bran	1:1	9.0	83.3
Notonectids + prawn	1:1	8.9	28.0
Notonectids + fat-free fish protein	1:1	8.7	64.0
Cow pea + wheat bran	1:1	8.5	86.0
Notonectids + rice bran	1:1	7.9	73.3
Mustard oil cake + wheat bran	1:1	8.1	84.0

Table V

Analysis of variance of the results of experiments with three-item feed mixtures

Source of variation	d.f.	Sum of squares	Mean sum of squares	F	Table value P=0.05	Table value P=0.01
Between sample means:	16	636.63	39.7894	31.62	1.65 (approx.)	2.01 (approx.)
Within samples:	493	620.37	1.2584			
Total:	509	1,257.00				

Table VI

Results of experiments with three-item feed mixtures, arranged in the order of efficiency of the mixtures

Feed mixture	Ratio	Average growth (mm)	Survival (percent)
Notonectids + prawn + cow pea	5:3:2	12.4	86.0
Notonectids + prawn + cow pea	3:5:2	11.8	88.0
Prawn + cow pea + wheat bran	1:1:1	11.1	96.0
Prawn + cow pea + rice bran	1:1:1	10.7	90.0
Prawn + cow pea + Bengal gram	1:1:1	10.6	96.0
Notonectids + prawn + cow pea	5:2:3	10.5	84.0
Notonectids + prawn + cow pea	10:7:3	10.5	60.0
Prawn + cow pea + ragi	1:1:1	10.0	88.0
Prawn + cow pea + fat-free fish protein	1:1:1	10.1	80.0
Notonectids + prawn + cow pea	4:5:1	9.7	82.0
Notonectids + rice bran + wheat bran	1:1:1	9.5	73.3
Notonectids + cow pea + fat-free fish protein	1:1:1	9.3	94.0
Notonectids + prawn + cow pea	6:3:1	9.1	60.0
Notonectids + cow pea + Bengal gram	1:1:1	8.9	92.0
Notonectids + cow pea + ragi	1:1:1	8.8	90.0
Notonectids + cow pea + wheat bran	1:1:1	8.5	96.0
Notonectids + prawn + cow pea	5:4:1	8.3	74.0

Table VII

Analysis of variance of the results of experiments with four-item feed mixtures

Source of variation	d.f.	Sum of squares	Mean sum of squares	F	Table value	
					P=0.01	P=0.05
Between sample means:	5	152.55	30.5100	37.41	2.26 (approx.)	3.11 (approx.)
Within samples:	210	171.28	0.8156			
Total:	215	323.83				

'F' once again is highly significant. By the 't' test, the smallest difference between sample means which is significant at 0.05 level was found to be 0.5. The results are given in Table VI.

From Table VI, improvement in growth and survival is more obvious in combinations of three items than in two item mixtures. Combinations of NPC in the ratios of 5:3:2 and 3:5:2, rank one and two respectively. It is interesting to note that with 10 combinations of NPC in different ratios, their nutritive behaviour had widely fluctuated and extended to the two extremes in ranking.

3.4 Four-item mixtures

With the indication in improvement of the diet in combination of three items, further attempts were made with mixtures of four items. Six combinations with NPC as the major constituents and others shown in Table VIII as the fourth item, were tested. The analysis of variance for the four-item mixtures is given in Table VII.

Thus 'F' remains highly significant with the smallest difference between sample means estimated as 0.4. The results of the analysis are given in Table VIII.

Table VIII

Results of experiments with four-item mixtures, arranged in the order of efficiency of the mixtures

Feed mixture	Ratio	Average growth (mm)	Survival (percent)
Notonectids + prawn + cow pea + common salt	50:27:20:3	11.5	90.0
Notonectids + prawn + cow pea + fish roe	3:3:2:2	11.4	76.0
Notonectids + prawn + cow pea + wheat bran	3:5:7:5	11.2	80.0
Prawn + cow pea + Bengal gram + wheat bran	2:1:1:1	10.9	94.0
Notonectids + prawn + cow pea + yeast	4:3:2:1	10.4	84.0
Prawn + cow pea + duck weed + wheat bran	1:1:1:1	9.7	94.0

The above suggests no appreciable improvement in growth and survival compared with three-item mixtures.

3.5 Five-item mixtures

With only two combinations tried, by 't' test, significant difference (t = 3.053) was observed. This 't' is with 82 d.f. and as the table value at 0.05 level, viz. 1.989, is much less than the calculated value, the treatments differ significantly.

The results of the two treatments with the average growth and survival data are given in Table IX.

Table IX

Results of experiments with five-item feed mixtures, arranged in the order of efficiency of the mixtures

Feed mixture	Ratio	Average growth (mm)	Survival (percent)
Notonectids + prawn + cow pea + Bengal gram + wheat bran	1:3:2:2:2	10.7	96.0
Prawn + cow pea + Bengal gram + wheat bran + fish protein with fat	5:4:4:4:3	10.1	84.0

The above results indicate a negative trend in the effect of the diet.

From the foregoing analyses the following treatments may be selected on the basis of their ranking, excluding fish roe.

Table X

The feed items and mixtures according to their rankings

Rank	Single item	Two-item mixture	Three-item mixture	Four-item mixture	Five-item mixture
I	Notonectids	Notonectids + cow pea 2:3	Notonectids + prawn + cow pea 5:3:2	Notonectids + prawn + cow pea + common salt 50:27:20:3	Notonectids + prawn + cow pea + Bengal gram + wheat bran 1:3:2:2:2
II	Prawn	Notonectids + yeast 4:1	Notonectids + prawn + cow pea 3:5:2	Prawn + Notonectids + cow pea + fish roe 3:3:2:2	Prawn + cow pea + Bengal gram + wheat bran + fish protein with fat 5:4:4:4:3
III	Fat-free fish protein	Prawn + yeast 4:1	Prawn + cow pea + wheat bran 1:1:1	Notonectids + prawn + cow pea + wheat bran 3:5:7:6	
IV	Fish protein with fat	Prawn + cow pea 2:3	Prawn + cow pea + rice bran 1:1:1	Prawn + cow pea + Bengal gram + wheat bran 2:1:1:1	

Table XI

Analysis of variance for the 18 experiments

Source of variation	d.f.	Sum of squares	Mean sum of squares	F	Table value	
					P=0.05	P=0.01
Between sample means:	17	646.81	38.0476	44.65	1.58 (approx.)	1.89 (approx.)
Within samples:	486	414.12	0.8521			
Total:	503	1,060.93				

Here also 'F' is highly significant and hence the treatments differ significantly. The smallest difference between sample means which is significant at 0.05 level is 0.5. In Table XII, the results are finally assessed.

Table XII

Feeds and feed mixtures arranged in the order of efficiency, as judged by growth and survival of carp fry

Feed mixture	Ratio	Average growth (mm)	Survival (percent)
Notonectids + prawn + cow pea	5:3:2	12.5	86.0
Notonectids + prawn + cow pea + common salt	50:27:20:3	11.8	90.0
Notonectids + prawn + cow pea	3:5:2	11.8	88.0
Notonectids + yeast	4:1	11.6	84.0
Prawn + cow pea	2:3	11.4	88.0
Notonectids + prawn + cow pea + fish roe	3:3:2:2	11.4	76.0
Prawn + cow pea + wheat bran	1:1:1	11.1	96.0
Notonectids + cow pea	2:3	11.1	86.0
Prawn + notonectids + wheat bran + cow pea	5:3:3:7	11.0	80.0
Prawn + cow pea + wheat bran + Bengal gram	2:1:1:1	10.9	94.0
Prawn + cow pea + rice bran	1:1:1	10.8	90.0
Prawn + cow pea + notonectids + wheat bran + Bengal gram	3:2:1:2:2	10.6	96.0
Notonectids	-	10.1	91.2
Prawn + cow pea + wheat bran + Bengal gram + fish protein with fat	5:4:4:4:3	10.1	84.0
Prawn	-	9.6	85.0
Fat-free fish protein	-	8.9	90.0
Fish protein with fat	-	8.8	56.0
Prawn + yeast	4:1	8.2	70.0

This table shows that a mixture of notonectids, prawn and cow pea in the ratio of 5:3:2 was most effective as a balanced artificial feed for carp fry. It has also been established that notonectids followed by prawn in combination with other feeds invariably yielded satisfactory results, thereby indicating their superiority in nutritive value, as well as their importance as the initial raw material.

4 CHEMICAL ANALYSIS OF IMPORTANT FEEDS

An attempt was made to analyse chemically the important items of feed used (Table XIII). The material was first thoroughly dried and powdered before analysis. Protein level was estimated by Kjeldahl's digestion method and fat was determined by ether extraction. Ash was estimated by total ignition and carbohydrate calculated as difference.

Table XIII indicates a high level of protein in notonectids, and carbohydrate in cow pea, while prawn is rich in ash and fat.

Table XIII

Chemical analysis of items of feed

	Item	Protein (percent)	Carbohydrate (percent)	Fat (percent)	Ash (percent)
1	Zooplankton	46.4	22.6	6.0	25.0
2	Notonectids	56.2	24.1	4.2	15.5
3	Prawn	18.8	32.8	8.4	40.0
4	Cow pea	21.46	71.2	3.7	3.6
5	Maize	7.13	79.9	4.5	8.5
6	Italian millet	11.66	75.0	6.9	6.4
7	Ragi	9.16	67.9	8.6	14.3
8	Mustard oil cake	30.6	29.2	10.2	30.0
9	Wheat bran	15.3	74.4	4.0	6.2
10	Rice bran	9.5	79.8	2.2	8.5

5 FIELD EXPERIMENTS

After the conclusion of the laboratory experiments, the relative merits of the selected diet were tested by conducting limited field experiments.

For this, ponds of comparable size and with more or less uniform ecological conditions were stocked with fry of *Catla catla*, *Labeo rohita*, *Cirrhina mrigala* and *Hypophthalmichthys molitrix* at the same rate of one million per hectare; here they were reared separately for 15 days. The fry were fed with the notonectids-prawn-cow pea (NPC mixture) diet, keeping mixture of mustard oil cake and rice bran as control feed in duplicate ponds. The feeding frequency was confined to once a day, the feed being broadcast on the water surface. The rate of feeding in each pond was:

First five days - Double initial [1/] weight of total fry
Next five days - Three times initial weight
Last five days - Four times initial weight

On the sixteenth day, fry from all the ponds were netted, their number assessed and growth recorded. The final data are as given in Table XIV.

Table XIV

Species	Mustard oil cake + rice bran mixture			NPC mixture		
	Average growth (mm)	Average growth (g)	Survival (percent)	Average growth (mm)	Average growth (g)	Survival (percent)
C. catla	18.6	0.0635	51.5	26.86	0.1615	74.37
L. rohita	19.53	0.0715	46.67	26.00	0.1655	53.8
C. mrigala	-	-	-	27.30	0.223	55.32
H. molitrix	24.8	0.1582	44.01	27.25	0.2825	45.52

[1/] Initial weight of fry stocked was determined on the basis of 0.0014 g as average weight of fry.

From the above data, the superiority of NPC mixture over the commonly used mustard-oil-cake-rice-bran mixture as a supplementary feed is obvious and could be considered as a suitable nursery diet.

6 DISCUSSION

In discussing the comparative merits of the above suggested mixtures as a fish diet, it may be relevant to consider the various feed items that are widely used in other countries as fish feeds. These include beef liver, beef heart, horse meat, hog spleen (frozen), meat scraps, tripe, lard, tankage, liver oils, whitefish meal, canned fish, cooked carp, silkworm pupae, white ants, gelatin, white of egg, dry butter milk, dry skim milk, casein (commercial), rice or wheat powder, rice bran, tapioca, cellu flour, oatmeal, soybean meal and milk, oil cakes, penicillin mat, brewer's yeast, Ipomoea stem, water hyacinth shoots, etc.

From the above incomplete list of supplementary feeds, it is obvious that the protein-rich costly items are beyond the means of fish farmers in a developing country like India. Hora and Pillay (1962) have recorded the various supplementary feeds used by fish culturists in the east and south-eastern countries of Asia. Among them animal material, except silkworm pupae and white ants, is conspicuous by its absence.

As the inherent productive potential of a pond is utilized not only by the fish, but also by the other plants and animals, it may be argued that fish production is likely to be greater if these other organisms are absent, unless they can be used for fish production. The present work shows that considerable quantities of insects and small commercially unimportant prawns growing in a pond provide an effective protein-rich fish-food, and that these organisms are not waste products.

The use of two protein items, namely notonectids and prawn, in the mixture evolved, could be justified by the well-known nutrition policy according to which a diet is likely to be more complete and better balanced in amino acids if it relies on a variety of protein sources rather than on a single source (Almquist, undated). Recent studies on carp nutrition by Hepher and Chervinski (1965) suggest an increase in fish yield when common carp (Cyprinus carpio) are fed on a protein-rich diet, an observation supported by the present work. Though no growth-limiting influence was apparent on the various species of carp fry tested with the present protein-rich diet, the authors do not claim that this suggested new supplementary feed is the optimum balanced diet in all nutritive requirements. Further work towards that end is essential.

An interesting point observed is its suitability for feeding all the cultured Indian carps, common carp and Chinese carps. Among the Indian carps, Catla catla is known for its selective plankton feeding habit. However, laboratory as well as field experiments demonstrated conclusively that this species could feed and grow satisfactorily on NPC mixture.

The economics of the feed depend largely on the availability of notonectids and prawns from the ponds of a fish farm. Normally, the insects could be collected in large quantities from nursery and rearing ponds throughout the year. Sample collections made from three 0.12 hectare ponds at Cuttack weighed 10,7 and 5 kilograms respectively in single hauls. The ratio of wet and dry weight has been found to be 3:1. Similarly, natural occurrence of small prawns, Macrobrachium lamarrei in nursery and rearing waters in considerable quantity is a common feature of many fish farms in India. While the two important items are thus available at almost no cost, the third item, cow pea, is a common cereal of relatively low cost. Where the prawn is not readily available, dry prawn from the market could be used at competitive rates. The field trials however demonstrated that the expenditure involved in feeding could be considered very favourable in relation to the returns from higher production of healthy fry.

Use of aquatic insects as natural food by insectivorous species of fishes, such as largemouth bass and bluegill bream (Howell et al., 1941), and by most of the perches, murrel, minnows, catfish, etc., is an established practice. Natural feeding, to a limited extent, on insects by common carp and some barbels of the carp family are also recorded. Hence, insects and prawns could be considered as suitable feeds for carps in general, provided these items are made available to them in a consumable and digestible condition. This suggests the possibility of utilizing terrestrial insect populations in fish feed.

Throughout the experiments, both in laboratory and field, none of the fry of the various species showed any symptom of dietary disease, which can also be considered in favour of the diet.

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8 REFERENCES

Alikunhi, K.H., 1952 On the food of young carp fry. J.zool.Soc.India, 4(1):77- 84

__________, 1956 Fish culture in India. Fm.Bull., Delhi, (20):144 p.

Alikunhi, K.H., H. Chaudhuri and V. Ramachandran, 1954 On the role of plankton in the survival and growth of carp fry in nursery ponds. In Symposium on marine and freshwater plankton in the Indo-Pacific, Bangkok, January 25th and 26th, 1954. Bangkok, IPFC, pp. 99-103

__________, 1955 On the mortality of carp fry in nursery pond and the role of plankton in their survival and growth. Indian J.Fish., 2:257-313

Almquist, H.J., d.u. Proteins and amino acids in animal nutrition. New York, U.S. Industrial Chemicals Co., Division of National Distillers Products Corporation, 32 p.

Brookway, D.R., 1953 Fish food pellets show promise. Progr.Fish Cult., 15(2):92-3

Hepher, B. and J. Chervinski, 1965 Studies on carp nutrition - The influence of protein-rich diets on growth. Bamidgeh, 17(2):31-46

Hickling, C.F., 1962 Fish culture. London, Faber and Faber, 295 p.

Hora, S.L. and T.V.R. Pillay, 1962 Handbook on fish culture in the Indo-Pacific Fisheries region. FAO Fish.tech.Pap., (14):204 p.

Howell, H.H., H.S. Swingle and E.V. Smith, 1941 Animal matter preferred by game fish, five years' experiments indicate. Ala.Conserv., 1941:2 p.

Kawamoto, N.Y., 1957 Production during intensive carp culture in Japan. Progr.Fish Cult., 19(1):26-31

Ling, S.W., 1957 Report to the Government of Thailand on the development of inland fisheries. Rep.FAO/ETAP, (653):50

Mitra, G.N. and P. Mohapatra, On the role of zooplankton in the nutrition of carp fry.
1956 *Indian J.Fish.*, 3:299-310

Natarajan, M.V. and A. Srinivasan, Proximate and mineral composition of fresh-water fishes.
1961 *Indian J.Fish.*, 8(2):422-9

Palmer, D.D., *et al.*, The effect of retardation of the initial feeding on the growth and
1951 survival of salmon fingerlings. *Progr.Fish Cult.*, 13(2):55-62

Palmer, D.D., L.A. Ribinson and R.E. Burrows, Feeding frequency: its role in the rearing
1951 of blue black salmon fingerlings in troughs. *Progr.Fish Cult.*, 13(4):205-12

Phillips, A.M., Jr. *et al.*, Comparison of hatchery diets and natural food. *Progr.Fish Cult.*,
1954 16(4):153-7

__________, The effects of supplemental fats in the diet of brook trout. *Progr.Fish Cult.*,
1952 14(1):19-22

Schäperclaus, W. (Transl. F. Hund), Text-book of pond culture. *Fish.Leafl., Wash.*, (311):
1933 260 p.

Seaman, W.R., Feeding of cooked carp to hatchery trout in Colorado. *Progr.Fish Cult.*,
1951 13(4):227-8

Wolf, L.E., Comparison of yeast and penicillin mat as supplements to dry meal diets for
1951a brown trout. *Progr. Fish Cult.*, 13(3):117-20

__________, Diet experiment with trout. *Progr.Fish Cult.*, 13(1):17-21
1951b

__________, Experiment with canned fish as food for trout. *Progr.Fish Cult.*, 13(2):95-7
1951c

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EXPERIMENTS WITH SUPPLEMENTAL FEEDS FOR CHANNEL CATFISH

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Abstract

Fingerling channel catfish were fed with diets of dry feed in 12 polyethylene-lined earthen ponds where water level was maintained at 0.0582 surface hectare.

Diets contained: 25 percent protein and 1,874 calories per kg (metabolizable energy); 25 percent protein and 2,168 calories; 25 percent protein and 1,874 calories but low in animal protein; and 30 percent protein and 2,316 calories.

Conversions near one kg of feed per kg of fingerling fish were obtained with all four diets. Survival of 11,450 fish stocked was 95.17 percent.

Large and small age class II fish stocked in combination or separately required slightly over two kg of feed to produce one kg of fish. A difference in initial average weight of one g between large and small fish resulted in a difference of 3.97 g in final weight.

In progeny tests, 170 g of fry stocked in each of 6 kg during June produced fingerlings 10.6 to 19.5 g in average weight.

ESSAIS DE DIVERSES FORMULES ALIMENTAIRES POUR L'ELEVAGE DU CHANNEL CATFISH (ICTALURUS PUNCTATUS)

Résumé

Quatre formules d'aliments secs ont été essayées pour le nourrissage d'alevins de channel catfish placés dans 12 bassins en terre doublés de polyéthylène, où le niveau de l'eau était maintenu de manière à avoir une superficie de 0,0582 ha.

Les formules utilisées étaient les suivantes: 25 pour cent de protéines et 1.874 calories par kg (énergie métabolisable); 25 pour cent de protéines et 2.168 calories; 25 pour cent de protéines et 1.874 calories, mais teneur faible en protéines animales; enfin, 30 pour cent de protéines et 2.316 calories.

Avec les quatre formules on a obtenu des taux de conversion approchant de l'unité un kilo d'aliments par kilo d'alevins. Les 11.450 poissons utilisés pour l'expérience ont survécu dans la proportion de 95 17 pour cent.

Avec les poissons de classe d'âge II, petits et grands, placés ensemble ou séparément, il fallait légèrement plus de deux kilos d'aliments pour produire un kilo de poisson. Un écart initial d'un gramme dans le poids moyen des poissons donnait, en fin d'expérience, un écart de poids de 3,97 grammes.

Lors d'essais de descendance, on a obtenu, en déversant au mois de juin 170 g de fretin dans 6 étangs différents, des fingerlings pesant en moyenne de 10,6 à 19,5 grammes.

EXPERIMENTOS CON ALIMENTOS SUPLEMENTARIOS PARA EL BAGRE DEL CANAL

Extracto

Se alimentaron jaramugos del bagre del canal con cuatro dietas de productos secos en 12 estanques de tierra revestidos de polietileno y en los que el nivel del agua se mantuvo a 0,0582 por hectárea de superficie.

Las dietas contenían: 25 por ciento de proteínas y 1.874 calorías por kg (energía metabolizable); 25 por ciento de proteínas y 2.168 calorías; 25 por ciento de proteínas y 1.874 calorías pero con escasas proteínas de origen animal; y 30 por ciento de proteínas y 2.316 calorías.

Con las cuatro dietas se logró un índice de conversión de un kg de alimento en un kg de pececillos. De los 11.450 peces sobrevivió el 95,17 por ciento.

Los peces grandes y pequeños de la clase II que se hallaban juntos o separados requirieron algo más de dos kg de alimentos para producir un kg de peces. Una diferencia de un gramo en el peso medio inicial entre los peces grandes y pequeños se tradujo en una diferencia de 3,97 gramos en el peso final.

En los ensayos de progenie, 170 g de jaramugos existentes en cada uno de los seis estanques durante el mes de junio produjeron pececillos pequeños de 10,6 a 19,5 gramos de peso medio.

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1 INTRODUCTION

Swingle (1958) reported on experiments of growing channel catfish, Ictalurus punctatus, to marketable size by supplemental feeding with dry pelleted feeds. Tiemeier and Elder (1960) conducted studies on supplemental feeding of this fish. Tiemeier et al.(1964 and 1965) found a diet containing 25 percent protein and an energy to protein ratio of 34:1 as efficient as diets containing 30 and 35 percent protein. Nail (1962) and Tiemeier et al. (1965) found a sparing effect of carbohydrates on protein in comparing diets containing similar percentages of protein but different quantities of energy.

The present investigations were conducted to study growth and production of various sizes and stocking combinations of channel catfish when fed pelleted feeds.

Cooperating in the experiments were the Kansas State University Agricultural Experiment Station, Kansas Forestry, Fish and Game Commission, Federal Aid to Fisheries Project No. F-12-R-1 and Project No. 4-1-R-1 of the Bureau of Commercial Fisheries and U.S. Army Corps of Engineers.

2 METHODS AND EXPERIMENTS

Twelve nearly identical polyethylene-lined earthen ponds at the Tuttle Creek Fisheries Research Laboratory were stocked with 950 fingerling channel catfish each in April 1965. Beginning April 14, identical amounts of dry pelleted feed were supplied to fish in each pond till August 29. Four diets were given and each was supplied to fish in three randomly selected ponds. Fish were fed six days each week but not on the days they were weighed. Ten groups of five fish from a seining of several hundred fish were weighed at two-week intervals. Starting June 8, each pond was supplied an amount of feed equal to 4 percent of the total average weight of fish in all 12 ponds, based on the assumption that all fish stocked had survived. Adjustments in amount of feed were made every two weeks. Feeding ceased on August 29, and 20 groups of five fish were weighed from each pond on August 30. All fish were counted when removed during the next few days.

The various ingredients in four diets (Tables I and II) were calculated to provide: (Z-14) 25 percent protein and a metabolizable energy to protein ratio of 34:1; (Z-15) 25 percent protein and a ratio of 38:1; (Z-16) 25 percent protein but low in animal proteins and high in plant proteins with an energy ratio of 34:1; and (Z-17) 30 percent protein and an energy to protein ratio of 34:1.

Table I

Analyses of various diets, 1965

Diets	Z-14	Z-15	Z-16 3/	Z-17
Protein (percent) 1/	25	25	25	30
Protein (percent) 2/	25.7	25.3	27.3	31.0
Fat (percent) 2/	4.4	4.2	3.4	4.5
Ash (percent) 2/	8.2	8.1	9.1	8.5
Fibre (percent) 2/	5.9	5.2	5.9	5.2
Metabolizable energy (Kcals/kg)	1,874	2,168	1,874	2,316
Metabolizable energy to protein ratio	34:1	38:1	34:1	34:1

1/ Calculated from values in feed analyses tables

2/ Determined by AOAC methods

3/ Contains low animal protein and high plant protein

Experimental formulae were calculated using a computer and the results were used in preparing diets by Kansas State University Department of Grain Science and Industry. Diets were prepared as 0.48 cm pellets and as granules for the fry fish.

Some channel catfish fed as fingerlings during 1964 were stocked in a farm pond during the winter of 1964-65. During April, this pond was seined and fish were classified as large if they weighed approximately 70 g or more and small if they weighed less. The left pelvic fin was clipped on large fish and the right pelvic fin on small fish. Fish were stocked in polyethylene-lined ponds.

Table II

Ingredients of various diets used in 1965 (in kg)

Diets	Z-14	Z-15	Z-16	Z-17
Soybean oil meal (44 percent)	84.6	106.0	253.9	209.9
Dehydrated alfalfa meal (17 percent)	100.0	50.0	50.0	50.0
Ground grain sorghum	176.5	273.9	146.0	
Wheat shorts				313.9
Wheat meal feed				207.9
Wheat bran	404.8	331.9	369.9	
Vegetable fat			4.8	4.3
Fish meal (60 percent)	88.0	88.0	25.0	5.0
Meat and bone meal (50 percent)	66.0	67.5	25.0	84.0
Blood meal	18.6	20.5		
Distiller's dried solubles	48.8	47.5	49.8	50.2
Sesame oil meal			38.0	
Dicalcium phosphate	5.7	6.2	25.7	17.7
Salt	5.0	5.0	5.0	5.0
Limestone		1.3	4.5	
d 1 methionine	0.9	0.9	1.0	0.7
Lyamine - 50 1/			0.2	
Vitamin premix 2/	1.0	1.0	1.0	1.0

1/ (50 percent lysine) supplied for this study by Merck and Co. Inc., Rathway, New Jersey

2/ Supplies per ton of finished feed: 10 mg vitamin B_{12}, 4 g riboflavin, 8 g d calcium pantothenate, 12 g niacin, 40 g choline chloride, and 10 g aureomycin.

Various combinations of large and/or small fish were stocked in ponds as follows:

(i) To determine effects on growth obtained by stocking an equal biomass of large and small fish; equal weights (3,405 g) of large and an equal weight of small fish was stocked in ponds Nos. 2 and 6. An identical amount of feed (Z-14) was supplied to fish in each pond. Fish were weighed at two-week intervals and removed in September.

(ii) To compare growth in ponds stocked with the same number of large or small fish but having different biomass, ponds Nos. 3 and 10 were each stocked with 179 large fish and ponds Nos. 8 and 12 with 179 small fish. Similar percentage of feed (4 percent daily of Z-14) was given daily to all fish but large fish in ponds 3 and 10 were fed more in total weight. Fish were weighed at two-week intervals.

On June 14, 170 g of newly hatched channel catfish from six different spawns were obtained from the Kansas Forestry, Fish and Game Commission hatchery. Each spawn was stocked in a separate pond. Granulated feed containing 35 percent protein was fed twice daily, seven days per week. An attempt was made to feed more feed than the fish would eat. After July 16, 5 percent of the total average weight of fish was supplied daily on the basis of 5,000 fish in each pond. Five groups of 10 fish were weighed at two-week intervals starting July 16. Fish were fed to October 1 when 10 groups of 10 fish were weighed. All fish were weighed and removed shortly after October 1.

Water temperatures were taken at 7 a.m. and 3 p.m. daily (Table III) at the surface and 1.37 metres depth in one pond. Extremely high and sudden temperature decreases were not encountered during the feeding period.

Table III

Average water temperature (^{o}C) at 7 a.m. and 3 p.m.
taken near the surface and at 1.37 m (pond No.1, 1965)

Period	a.m.		p.m.	
	surface	1.37 m depth	surface	1.37 m depth
June 8 to 18	23.5	23.3	26.9	23.7
June 21 to July 4	24.6	24.6	28.4	24.8
July 5 to 16	26.6	26.5	31.3	27.0
July 17 to 30	26.1	16.3	29.4	26.4
August 2 to 13	25.1	25.3	29.7	26.0
August 16 to 28	25.7	25.7	28.2	26.3
August 30 to Sept. 10	23.3	23.1	26.8	24.6

3 RESULTS

3.1 Fingerlings

Mean weight of 950 fingerling channel catfish was 2.32 g when counted and stocked in 12 ponds during April 1965. Data on stocking and recovery are presented in Table IV. Percentage gain in weight, gain per pond, rates of gain, conversions and feed costs are given in Table V. Weights of protein and kilocalorie content and their utilization by fingerling fish are presented in Table VI.

Table IV

Stocking and survival of fingerling channel catfish, 1965

Pond	Diets	No. fish stocked	No. fish recovered	Percentage survival
9	Z-14	950	943	99.3
23	Z-14	950	925	97.4
25	Z-14	950	919	96.7
Total for	Z-14	2850	1787	97.8
7	Z-15	950	909	95.7
19	Z-15	950	924	97.3
27	Z-15	950	905	95.3
Total for	Z-15	2850	2738	96.1
5	Z-16	1000	918	91.8
15	Z-16	950	898	94.5
17	Z-16	950	915	96.3
Total for	Z-16	2900	2731	94.2
11	Z-17	950	844	88.8
13	Z-17	950	886	93.3
21	Z-17	950	911	95.9
Total for	Z-17	2850	2641	92.7
Total for (12) ponds		11450	10897	95.17

Table V

Percentage gain in weight, gain per pond, rate of gain, conversion and feed cost for fingerlings, 1965

Pond	Diets	Percent. 1/ gain	gain kg	Gain rate 2/ kg/ha	Conversion rate	Cost per 3/ kg fish (U.S.$)
9	Z-14	3589	76.9	1322.7	1.04	0.1007
23	Z-14	3512	75.2	1293.5	1.06	0.1025
25	Z-14	3669	78.8	1353.1	1.01	0.0976
Mean	Z-14	3591	76.95	1323.4	1.04	0.098

(cont'd)

1/ Fish average 2.32 g when stocked

2/ Water level maintained near 0.0582 surface ha

3/ Cost per kg of feed: Z-14:0.0968; Z-15:0.0976; Z-16:0.0873; Z-17:0.0950

Table V (cont'd)

Pond	Diets	Percent. gain [1]	gain kg	Gain rate kg/ha [2]	Conversion rate	Cost per kg fish (U.S.$) [3]
7	Z-15	3515	73.0	1256.5	1.09	0.107
19	Z-15	3333	71.2	1225.4	1.12	0.109
27	Z-15	3507	75.1	1291.3	1.06	0.104
Mean	Z-15	3418	73.1	1257.7	1.09	0.107
5	Z-16	3440	73.5	1264.1	1.09	0.095
15	Z-16	3321	71.0	1220.7	1.12	0.098
17	Z-16	3520	75.4	1296.5	1.06	0.093
Mean	Z-16	3427	73.3	1260.4	1.09	0.095
11	Z-17	3420	73.2	1258.2	1.09	0.104
13	Z-17	3574	76.5	1316.8	1.04	0.099
21	Z-17	3617	77.5	1332.8	1.03	0.098
Mean	Z-17	3385	75.7	1302.8	1.05	0.100

[1] Fish average 2.32 g when stocked

[2] Water level maintained near 0.0582 surface ha

[3] Cost per kg of feed: Z-14:0.0968; Z-15:0.0976; Z-16:0.0873; Z-17:0.0950

Table VI

Protein and kilocalories and their utilization
by fingerlings, 1965

Diets	Z-14	Z-15	Z-16	Z-17
Percent protein	25	25	25	30
Kg feed fed (3 ponds)	239.5	239.5	239.5	239.5
Kg protein fed (3 ponds)	59.9	59.9	59.9	71.9
Kg fish produced (3 ponds)	230.8	219.4	219.9	227.2
Grams protein per kg fish produced	259.6	273.1	272.4	316.5
Kcals per kg of feed [1]	1874	2168	1874	2316
Kcals per kg of fish produced	1941.7	2285.5	2040.9	2369.3
Average production (kg/ha)	1323	1258	1260	1303

[1] Calculated from feed formula tables using metabolizable energy values

3.2 Age Class II fish

Six ponds were stocked with various numbers and total biomass of age class II fish (Tables VII and VIII). Data on survival are given in Table VII and those for gains in Table VIII. Table IX presents information on rates of conversion and utilization of protein and energy in the supplemental feed. A comparison of results obtained by stocking large and small age class II fish is given in Table X.

Table VII

Stocking and recovery of age class II fish, 1965

Pond	Fish stocked	Fish recovered	Percentage survival
2 large	35	35	100
2 small	67	65	97
2 total	102	100	Mean: 98
6 large	31	31	100
6 small	66	66	100
6 total	97	97	Mean: 100
3 large	179	154	86
10 large	179	178	99.4
3 and 10 total	358	332	Mean: 92.7
8 small	179	179	100
12 small	179	179	100
8 and 12 total	358	358	Mean: 100

Table VIII

Stocking and recovery weights (in g) and gains of age class II fish, 1965 1/

Pond 1/	Stocking weight		Recovery weight		Average gain	Total gain	Percentage gain
	Average	Total	Average	Total			
2 large	97.3	3,405	637	22,295	539.7	18,890	555
2 small	51.5	3,405	433	28,145	381.5	24,740	727
2 total		6,810		50,440		43,630	Mean: 641
6 large	109.0	3,405	653	20,243	544.0	16,838	495
6 small	51.6	3,405	467	30,822	415.4	27,417	805
6 total		6,810		51,065		44,255	Mean: 650

(cont'd)

1/ Ponds were stocked with small, large or a combination of various sizes of fish

Table VIII (cont'd)

Pond[1]	Stocking weight		Recovery weight		Average gain	Total gain	Percentage gain
	Average	Total	Average	Total			
3 large	91.9	16,456	547	84,238	455.1	67,782	412
10 large	76.1	13,620	450	80,100	373.9	66,480	488
3 + 10 total		30,076		164,338		134,262	Mean:446
8 small	61.3	10,980	383	68,557	321.3	57,577	524
12 small	60.9	10,896	397	71,063	336.1	60,167	552
8 + 12 total		21,876		139,620		117,744	Mean:538

[1] Ponds were stocked with small, large or a combination of various sizes of fish

Table IX

Gain, conversion, cost, kilocalories and protein required to produce age class II fish and production rate per ha, 1965

Pond	Total gain (g)	Total feed (g)	Conversion	Cost per kg fish (U.S. cents)[1]	Calories per kg gain	Protein per kg gain (in g)	Gain per ha (kg)
2	43,630	90,430	2.07	20.0	3,879	517.9	750
6	44,255	90,430	2.04	19.7	3,831	511.3	762
2 + 6	87,855	180,860	2.06	19.9	3,859	515.7	
3 [2]	67,782	178,780	2.64	25.5	4,946	661.2	856
10	66,480	178,780	2.69	26.0	5,019	672.2	1,144
3 + 10	134,262	357,560	2.66	25.7	4,983	665.6	
8	57,577	135,530	2.35	22.7	4,382	588.5	990
12	60,167	135,530	2.25	21.8	4,216	562.0	1,035
8 + 12	117,744	271,060	2.30	22.3	4,309	575.2	

[1] Z-14 feed, 25 percent protein, 1,874 calories per kg, cost U.S.$ 0.0968 per kg

[2] Pond 0.0792 surface ha, all others 0.0582

Table X

Growth (in g) obtained by stocking large and
small age class II fish, 1965

Pond	Stocking weight		Recovery weight		Weight gain		Percentage gain
	Average	Total	Average	Total	Average	Total	
			Large Fish [1]				
2	97.3	3,405	637	22,295	539.7	18,890	555
6	109.0	3,405	653	20,243	544.0	16,838	495
3	91.9	16,456	547	84,238	455.1	67,782	412
10	76.1	13,620	450	80,100	373.9	66,480	488
Total		36,886		206,876		169,990	
Mean	87.0		519.7		427.1		461
			Small Fish [2]				
2	51.5	3,405	433	28,145	381.5	24,740	727
6	51.6	3,405	467	30,822	415.4	27,417	805
8	61.3	10,980	383	68,557	321.3	57,577	524
12	60.9	10,896	397	71,063	336.1	60,167	552
Total		28,686		198,587		169,901	
Mean	58.4		406.1		347.4		592

[1] 93.9 percent or 398 of 424 stocked fish were recovered

[2] 99.6 percent or 489 of 491 stocked fish were recovered

3.3 Fry

Six lined ponds were each stocked with 170 g of newly hatched channel catfish on June 14. Fish stocked in each pond were from one spawn. Results of this experiment are given in Table XI.

Table XI

Production of channel catfish fry, 1965 [1]

Pond	Weight of fish (kg)	Mean weight (g)	No. of fish	Production (kg/ha)	Production (No./ha)
16	67.8	14.54	4,657	1,165	71,469
20	59.0	10.61	5,564	1,015	85,387
22	46.8	11.56	4,048	804	62,100
24	71.6	17.18	4,198	1,231	64,425
26	77.4	17.06	4,535	1,331	69,596
28	77.7	19.49	4,012	1,334	61,569

[1] Stocked each 0.0582 surface ha pond June 14 with 170 g of newly hatched fish

Apparently the survival was very high and the experiment indicates the possibilities of rearing large numbers of fry to fingerlings by feeding with granulated feeds.

4 DISCUSSION

Variations in survival of fingerlings were greater in replicates of diets than between diets (Table IV). Mean survival in the 12 ponds was 95.2 percent compared to 96.8 percent obtained in 1964 (Tiemeier et al., 1965) when fish weighing 8 g were initially stocked.

A total gain of 897.3 kg or rate of gain of 74.8 kg per pond was obtained by stocking 11,450 fish averaging 2.32 g in 12 ponds in 1965. Tiemeier et al. (1965) obtained a total gain of 2,017.2 kg or a rate of gain of 126.2 kg per pond by stocking 32,000 fingerlings averaging 8 g in 16 ponds during 1964. Stocking 109.6 percent more fish per pond in 1964 produced an additional total weight gain per pond of 30.8 kg compared with 1965.

Rates of feed conversions were uniform and many conversions of less than 1.0 kg feed per kg of gain were calculated at the two-week weighing periods. Fish in all ponds were uniform in size.

Diets Z-14 and Z-16 were prepared to provide 1,874; Z-15:2,168 and Z-17:2,316 kcals per kg of feed. Kilocalories required to produce a kg of fish varied from 1,914.7 for diet Z-14 to 2,369.3 for Z-17 (Table VI). Phillips et al. (1963) concluded that trout could be reared on meat-meal mixtures at a rate of 4,628.4 kcals per kg of body weight. Kilocalories required in 1965 experiments on fingerlings were 50 percent of requirements in 1964 experiments (Tiemeier et al., 1965).

Proteins were efficiently utilized in all feeding regimes (Table VI). Those fish fed diet Z-14 required 259.69 to produce a kg of fish and greatest requirement was 316.5 g with diet Z-17 (30 percent protein). Sparing action of carbohydrates to save protein as reported by Nail (1962) and Tiemeier et al. (1965) was not evident. Diets Z-14 and Z-16, containing 1,874 kcals per kg were as efficient as Z-15 (2,168 kcals) and Z-17 (2,316 kcals). Diet Z-16, containing low animal protein was as efficient as diets Z-14 and Z-15 that contained more animal proteins.

Cost of diets (Table V) included retail price of ingredients, cost of processing and bagging. Diet Z-16 was cheapest because some plant proteins were substituted for animal proteins. Feed cost to produce a kg of fingerling fish varied from 0.095 U.S.$ for diet Z-16 to 0.107 for diet Z-15. Favourable water temperatures as indicated (Table III) facilitated excellent growth and conversions.

Ponds Nos. 2 and 6 were stocked with 3,405 g but different numbers of large and small fish (Table VII). Ponds Nos. 3 and 10 were each stocked with 179 large fish but ponds Nos. 8 and 12 were each stocked with 179 small fish. Survivals were excellent except for pond No.3 where lower percentage gain and comparatively fewer kg gain per ha were obtained (Table VIII).

Total gain by 491 small fish was almost identical with gain of 424 large fish (Table X). Large fish gained more weight per fish than small fish but percentage gain was greater for small fish. Wohlfarth et al. (1965) found that carp progenies with larger initial weights tend to show larger weight gains than progenies with lower initial weights. They found that one gram difference in initial weight was associated with three or four grams difference in weight gain. Fish in our experiments were from several progenies but our data indicated that a difference in initial weight of small and large fish of 28.6 g was associated with a difference of 113.6 g in final weights. From this, it can be observed that a difference of one gram in initial weight resulted in a difference of 3.97 g in final weight.

The weight of feed required to produce a kg of fish was 2.06 - 2.3 kg. Feed was more efficiently utilized in early summer and gradually decreased as fish increased in size. This probably indicated that the larger fish could not efficiently utilize 4 percent of their weight in daily feedings. Kilocalories and grams of protein required to produce a kg of fish (Table IX) were similar to those required by fingerling fish in 1964 experiments (Tiemeier *et al.* (1965) or twice the requirements for producing fingerlings in 1965 experiments.

5 REFERENCES

Nail, M.L., The protein requirement of channel catfish. *Proc.Conf.stheast.Ass.Game Commrs.*,
1962 16:307-16

Phillips, A.M. Jr., *et al.*, The effect of diet mixture and calorie source on growth,
1963 mortality, conversion, and chemical composition of brook trout. *Progr.Fish Cult.*, 25(1):9-14

Swingle, H.S., Experiments on growing fingerling channel catfish to marketable size in
1958 ponds. *Proc.Conf.stheast.Ass.Game Commrs.*, 12:63-72

Tiemeier, O.W. and J.B. Elder, Growth of stunted channel catfish. *Progr.Fish Cult.*, 22(4):
1960 172-76

Tiemeier, O.W., C.W. Deyoe and S. Wearden, Supplemental pellet feeding of channel catfish.
1964 *Rep.Progr.Kans.Agr.Exp.Sta.*

__________, Effects on growth of fingerling channel catfish of diets containing two
1965 energy and two protein levels. *Trans.Kans.Acad.Sci.*, 68(1):180-6

Wohlfarth, F., *et al.*, Activities of the carp breeders union in 1964. *Bamidgeh*, 17(1):9-15
1965

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III/E-7

THE EFFECT OF COBALT, VITAMINS, TISSUE PREPARATIONS AND ANTIBIOTICS ON CARP PRODUCTION

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THE EFFECT OF COBALT, VITAMINS, TISSUE PREPARATIONS AND ANTIBIOTICS ON CARP PRODUCTION

Abstract

Vegetable fodder is used for growing carp (*Cyprinus carpio*) under intensive conditions in the U.S.S.R., but the growth rate slows markedly when the natural component in the food ration is less than 17 to 20 percent, as is usual in the high stockings adopted to obtain more production per unit area.

The growth-stimulating effects of various doses of the following substances were therefore investigated:

(i) Cobalt. This is part of vitamin B_{12} and concerned in nitrogen assimilation and synthesis of haemaglobin and muscular protein. The experiments showed that cobalt additions positively affect growth and productivity, both when added to fodder and when assimilated through food organisms which get it from cobalt-fertilized water.

(ii) Vitamins, particularly of the B group and D. The addition of four percent fodder yeast to rations of two-year-old carp increased growth rate by 16 percent and brought down food expenditure per unit gain by about 15 percent.

(iii) Tissue preparations, prepared from slaughter-house offal. These when added to rations of two-year carp at a rate of 7 g/kg gave a growth rate increase of 12 percent.

(iv) Antibiotics such as terramycin. Best results came from giving 20,000 units every three days; this raised growth by 9.5 percent and a fodder saving of 10.5 percent. Antibiotics are evidently concerned with protein metabolism and can make up to some extent for lack of animal proteins in the rations.

On the basis of these experiments the addition of these growth-stimulating substances to feed mixtures for carp is recommended.

INFLUENCE DU COBALT, DES VITAMINES, DES PREPARATIONS TISSULAIRES ET DES ANTIBIOTIQUES SUR LA PRODUCTION DE CARPES

Résumé

En U.R.S.S., l'alimentation d'appoint utilisée en pisciculture intensive de la carpe (*Cyprinus carpio*) est à base végétale, mais le taux de croissance s'abaisse nettement lorsque les constituants naturels de la ration tombent au-dessous de 17 à 20 pour cent, ce qui est généralement le cas avec les fortes charges employées pour accroître les rendements.

Aussi a-t-on étudié les effets sur la croissance des substances suivantes, employées à diverses doses.

(a) Cobalt -
Cet élément constitutif de la vitamine B_{12} joue un rôle dans l'assimilation de l'azote ainsi que dans la synthèse de l'hémoglobine et des protéines musculaires. Les expériences ont montré que l'adjonction de cobalt à la ration avait un effet bénéfique sur la croissance des carpes et sur la productivité des étangs, qu'il soit ajouté directement aux aliments d'appoint ou assimilé par l'intermédiaire d'organismes servant de nourriture et l'ayant absorbé dans une eau enrichie en cobalt.

(b) Vitamines (notamment vitamines du groupe B et vitamine D) -
L'adjonction aux rations de carpes de deux ans de 4 pour cent de levure a entraîné un relèvement de 16 pour cent de taux de croissance et réduit d'environ 15 pour cent les frais de nourrissage par unité de gain pondéral.

(c) Préparations tissulaires (provenant d'organes d'animaux de boucherie) -
Ces préparations, ajoutées à la ration de carpes de deux ans à raison de 7 g/kg, ont provoqué un relèvement de 12 pour cent du taux de croissance.

(d) Antibiotiques (notamment terramycine) -
Les meilleurs résultats ont été obtenus par l'administration de 20.000 unités tous les trois jours: accroissement de 9,5 pour cent du taux de croissance et économie de 10,5 pour cent sur le nourrissage. Il est évident que les antibiotiques ont une incidence sur le métabolisme protidique et peuvent compenser dans une certaine mesure le manque de protéines animales dans la ration.

Se fondant sur les résultats ci-dessus, l'auteur recommande l'adjonction à la ration alimentaire des carpes de ces substances stimulant la croissance.

EFECTO DEL EMPLEO DE COBALTO, VITAMINAS, PREPARACIONES DE TEJIDOS ORGANICOS Y ANTIBIOTICOS EN LA PRODUCCION DE CARPA

Extracto

En la URSS se utiliza forraje vegetal para alimentar a la carpa (Cyprinus carpio) en condiciones intensivas, pero la tasa de crecimiento desciende sensiblemente cuando el componente natural de la ración alimentaria es menor del 17 - 20 por ciento, como ocurre generalmente con las grandes densidades de reproblación utilizadas para obtener más producción por unidad de superficie.

En consecuencia, se investigaron los efectos estimuladores del crecimiento de distintas dosis de las sustancias siguientes:

i) Cobalto. Este forma parte de la vitamina B_{12} y está relacionado con la asimilación de nitrógeno y la síntesis de la hemoglobina y la proteína muscular. Los experimentos demostraron que la adición de cobalto influyó positivamente en el crecimiento y la productividad lo mismo cuando se añadió a los forrajes como cuando fué asimilado a través de organismos alimentarios que llegan a adquirirlo en aguas fertilizadas con cobalto.

ii) Vitaminas, particularmente del grupo B y D. La adición de cuatro por ciento de levadura de forraje a las raciones suministradas a las carpas de dos años aumentó la tasa de crecimiento en el 16 por ciento e hizo dismimuir el gasto en alimentos por unidad de ganancia en el 15 por ciento aproximadamente.

iii) Preparaciones de tejidos orgánicos, derivadas de resíduos de matadero. Cuando éstas se añadieron a las raciones de las carpas de dos años a razón de 7 g/Kg. dieron un aumento del crecimiento del 12 por ciento.

iv) Antibióticos tales como la terramicina. Se obtuvieron los mejores resultados proporcionando 20.000 unidades cada tres días; esto aumentó el crecimiento en el 9,5 por ciento e hizo obtener una economía de forraje del 10,5 por ciento. Los antibióticos están relacionados evidentemente con el metabolismo proteínico y pueden compensar hasta cierto grado la falta de proteínas animales en las raciones.

A base de estos experimentos se recomienda la adición de estas sustancias estimuladoras del crecimiento a las mezclas destinadas a la alimentación de la carpa.

1 INTRODUCTION

In view of its importance in intensive carp (Cyprinus carpio) culture in the U.S.S.R., studies were made of methods for increasing the efficiency of organic reserve vegetable fodder conversion when carp were fed under conditions of high stock density and sharply declining availability of fish-food organisms.

Previous studies have shown that growth of carp slows down sharply when the natural components in its food ration constitute less than 17 to 20 percent. This is usual in five-fold and six-fold stockings used with supplemental feeding to obtain higher production per unit area than when only natural food is used.

2 THE EFFECT OF COBALT ON CARP PRODUCTION

The VNIIPRH fish-feeding laboratory investigated the following micro-elements as growth stimulants for the carp: cobalt, a protein-vitamin preparation, fodder yeast, antibiotic terramycin and a "tissue" preparation. The improvement in the growth of animals when various growth stimulants are added to the food is mostly accounted for by improvement in the metabolism of the organism. Growth stimulants cannot substitute for food and they are most effective in nutritious rations as they contribute to assimilation of the nutrients. The study of various additions to vegetable fodder for the carp was carried out in ponds stocked with fish of common origin and of identical weight at the time of stocking. The experiments were conducted twice, and the results were compared with those obtained in controls.

Cobalt was studied from two points of view: as an additional micro-element to vegetable mixtures, and as a fertilizing micro-element dissolved in the water of fish breeding ponds. In conditions of dense stocking when the natural component of the food ration declines sharply the food should be physiologically good and balanced according to the complex of nutrients. In addition to organic substances (protein, fat, carbohydrates) it should contain mineral substances, and micro-elements in particular.

Cobalt which is part of vitamin B_{12} and is of primary importance in the formation of erythrocytes and the synthesis of haemoglobin, is essential for the normal activity of animals. Cobalt greatly affects the fermentation, intensifying the synthesis of muscular protein and the assimilation of nitrogen.

The influence of cobalt on physiological indices and the growth of under-yearlings and two-year-old carp was studied for the first time in the conditions of the central black soil zone (the "Niva" fishery of the Voronez region). Cobalt (cobalt chloride) was used in the experiments, the amount of cobalt being 0.08 mg to 1 kg of fish per 24 hours. This corresponds to 3.0 g cobalt chloride per ton of the fodder. The experiments and commercial experience of four years (1959-1962) have shown that cobalt chloride added to the fodder improved the haematological indices of under-yearling and two-year-old carp (the number of erythrocytes increased by 11 to 28 percent, and the haemoglobin content by 7 to 23 percent). Investigations have shown that adding cobalt to the fodder results in an increase in vitamin B_{12} in the liver of carp under-yearlings so that its deposition there in three weeks amounts to 2.1 mg, in six weeks to 3.57 mg, and in 11 weeks to 2.2 mg in contrast to 0.76, 0.88 and 0.73 in control fish that had no cobalt addition to the diet. Improvement in the physiological condition as a result of adding cobalt to the fodder allows an increase in growth rate of 30 percent in fingerlings and an average of 15-20 percent in two-year-old commercial fish, and the amount of fodder needed per unit gain diminishes by an average of 20 percent.

Observations on the effect of cobalt on the growth of fish and the productivity of ponds, carried out in the production conditions of the North-Caucasian zone, the Ukraine and the non-black-soil zone, have shown that the application of cobalt to carp food in different regions contributes to the growth of carp, reduces the amount of fodder per unit gain, and increases the productivity of ponds.

In contrast to the investigations described above on the effect of cobalt added to the diet, this micro-element was added to fish ponds as a fertilizer in another set of experiments. These investigations were based on the work done by Koval'skii et al. (1964) who had proved that cobalt added to a water-body is deposited in the silt, and remains there for several years. The first experiments in the fertilization of rearing ponds with cobalt chloride were made in 1962 by Krymova and Farberov in the Niva fishery of the Voronez region (Sukhoverkhov, Krymova and Farberov, 1963). It was found there that the application of cobalt increases the food supply of fish, raises the intensity of the feeding of fingerlings, and consequently contributes to the productivity of ponds. It was ascertained in 1963 that the application of 5 kg of cobalt chloride per ha increases its content in the water 2 to 2.8 times, and when the rate is 10 kg per ha its content increases three or four times. Adding cobalt to pond water resulted in an increase in the biomass of zooplankton and benthos. This also became richer in vitamin B_{12}, whereby the experimental pond fish got more natural food rich in cobalt and vitamin B_{12} than did the fish in the control ponds.

In 1964 the study of the after-effects of cobalt treatment showed that the content of cobalt in the water of the experimental ponds was 1.5 to 2 times higher than in non-fertilized ponds. The cobalt fertilization of ponds influenced the development of zooplankton and benthos and resulted in a higher content of vitamin B_{12} in food organisms.

The content of vitamin B_{12} in the body of a fingerling reared in a fertilized pond was 1.5 to 2 times higher than in one reared in non-fertilized ponds. Even greater differences of vitamin B_{12} were discovered in the liver of fingerlings. The fertilization of fish ponds with cobalt increased protein and fat deposited in the organs of fingerlings, which is very essential for raising their viability during the wintering period.

In 1963 when the pond water was first fertilized with cobalt only (without ammonium nitrate and superphosphate), at a rate of five kg of cobalt chloride per ha, the productivity of fish was 0.449 ton/ha, while in non-fertilized ponds it was 0.24 ton/ha. In 1964 when studying the after-effects of ammonium nitrate and superphosphate, it was ascertained that with the application of cobalt chloride the productivity of fish was equal to 0.61 ton/ha, and with the rate of cobalt chloride equal to 10 kg/ha the average fish production was 0.67 ton/ha. These investigations showed that cobalt positively affects the growth and productivity of carp, both when added to the fodder and when assimilated through food organisms which get it from the fertilized pond water.

3 THE EFFECT OF VITAMINS ON CARP PRODUCTION

The effect of vitamins on the growth of the rainbow trout is well-known, but their effect on carp when densely stocked and fed on artificial foods has hardly been studied. One of the reasons for a sharp decline in the growth rate of carp given the same rations but stocked at higher densities is, in our opinion, lack of vitamins of the B group. In warm-blooded animals a shortage of the vitamins of the B group adversely affects fermentation, decreases the assimilability of the food, and reduces productivity. It was therefore considered desirable to study the possibility of using fodder yeast as a source of these vitamins for carp.

Fodder yeast is a product of the biosynthesis of protein and vitamins produced during hydrolysis in pulp and paper manufacture. It is produced in the form of a powder containing 42 to 52 percent protein, 2 to 3 percent fat, 13 to 16 percent carbohydrates and 6 to 10 percent of mineral substances. A kilogram of fodder yeast contains the following: 18 mg vitamin B_1 (thiamin), 20-50 mg vitamin B_2 (riboflavin), 200-300 mg vitamin PP (nicotinamide or nicotinic acid), 50-100 mg pantothenic acid and 2,500-4,00 mg choline. Fodder yeast also contains provitamin D, which when treated with ultra-violet rays turns into vitamin D_2. At present pulp and paper plants produce fodder yeast treated with ultra-violet rays.

Sunflower oil cakes which are very often used as the main food and comprise 50 to 55 percent of mixed fodder for carp, are very poor in the vitamins of the B and D groups. They contain 3 mg/kg of vitamin B_2, 180 mg/kg of vitamin PP and 10-14 mg/kg of pantothenic acid. They lack vitamin B_1, vitamin D and choline. When sunflower oil cake is used as food, the addition of fodder yeast makes up for the lack of vitamin B_1 (thiamin); this is a component of ferments necessary for decarboxylation preventing water, fat, protein and carbohydrate metabolic disturbances in the organism. Vitamin D takes part in the mineral and energy metabolism and intensifies the absorption of calcium from the intestines and its deposition in the bones. Choline is necessary as a lipotropic factor promoting the formation of phospholipids in the liver; these prevent liver steatolysis and fat and carbohydrate metabolic disturbances caused by the unsatisfactory use of fodder.

Experiments carried out for two years (1958-1959) and the follow-up in commercial fisheries have shown that the addition of 4 percent of fodder yeast to the rations of a two-year-old carp increases its growth rate by approximately 16 percent, and brings down the food expenditure per unit gain by approximately 15 percent. Fodder yeast is also widely used as a component of the feed mixture for rainbow trout (Salmo gairdneri).

4 THE EFFECT OF TISSUE PREPARATIONS ON CARP PRODUCTION

In 1933, Filatov suggested that a tissue preparation should be used as biogenic stimulant (Filatov, 1948). He found out that the animal tissue separated from the organism does not die immediately, and for some time metabolic activity continues in it. Any live tissue separated from the organism and kept in unfavourable conditions is subject to a biochemical reconstruction. The substances which form as a result of this reconstruction when introduced into another organism intensify its biochemical development. Filatov called these substances biogenic stimulants.

The study of the effects of tissue preparation on warm-blooded animals has shown that they affect the whole of the animal, intensifying its defensive functions, and the secretory and assimilatory activity of the digestive organs. They intensify its metabolic development through the ferment systems which promote the secretion of the gastric juice, improve the assimilation of the food and speed up growth.

At present the tissue preparation is made of the organs of animals just slaughtered. The organs used for this purpose are: spleen, lungs, liver, lymphatic knots, bowels, tracheae with the thyroid gland, ovaries, pregnant wombs with embryos in the first half of the pregnancy (three to four months), eyeballs, etc. The above organs are subjected to five to six days' preservation at a temperature of 3 to 5°C, after which they are dried under pressure at a temperature of 150-200°C, and then pulverized, sieved and packed in paper bags. A number of meat processing plants produce this preparation on a commercial scale. Investigations have shown that this tissue preparation added to the rations of two-year-old carp during the warm summer of 1964, at the rate of 7 g per kg, or 7 kg per ton of a dry fodder mixture, increased the growth rate of the carp by 12.4-13.3 percent. At the same time this decreased the fodder used per unit of weight gain by 8.8 percent (Sukhoverkhov, et al., 1963). When testing different doses of the tissue preparation (7 g/kg without a 20-day interval, and 3.5 g/kg, 7 g/kg, 14 g/kg and 28 g/kg with a 20-day interval) in the conditions of the cold summer of 1965, the best dose proved to be 7 g/kg (7 kg/ton) of the dry fodder mixture, applied without a 20-day interval. This gave an increase in the growth of the two-year-old carp by 12.0 percent. At the rate of 3.5 g/kg (3.5 kg/ton) the growth increased by 8.2 percent. At the rates of 7.14 and 28 g/kg no increase in the growth was observed.

On the basis of the experiments, we consider it possible to recommend the addition of 7 g/kg of this tissue preparation to feed mixtures for feeding two-year-old carp.

The addition of growth-stimulating substances, i.e. cobalt, fodder yeast, and tissue preparation at the rate of 7 kg per ton of dry fodder (without an interval) promoted the growth of two-year-old carp in the commerical production ponds of the Osenka fishery in conditions of the cold summer of 1965. It also decreased the fodder used per unit weight gain by 20 percent compared with the diet when these substances were not added (Sukhoverkhov, Sidelnikov, Sidelnikova, and Gribanova, unpublished.

5 THE EFFECT OF ANTIBIOTICS ON CARP PRODUCTION

Antibiotics comprise the largest group among the known growth stimulants. At present antibiotics number several hundreds. Among these penicillin, streptomycin and tetracycline preparations are generally used to stimulate the growth of animals. Data on the effect of antibiotics on the growth of the carp are scarce. Although some scientists (Leonov, 1963) have observed that antibiotic preparations favourably affect the growth of the carp, no recommendations have been made on the doses to be applied.

To test the possibility and expedience of the application of antibiotics to carp fodder, grain-based terramycin was chosen. This choice was made for the following reasons. Terramycin, which belongs to the tetracycline group, possesses the most universal growth-stimulating effect on animals of different species; the micro-flora adapts to it quicker than to other preparations; in this preparation the antibiotic is organically bound to the substratum, which prevents it being washed away; the preparation retains its activity for six months which allows it to be used as an ingredient of a food mixture.

Experiments have been carried out to test different doses of terramycin, and in methods of applying it in the feeding of carp as an ingredient in diversified rations (Korneeva, 1963 and 1965). The growth-stimulating effect of the antibiotic varied from 5 to 25 percent. Doses tested ranged from 2,500 to 40,000 units per kg of fodder, and doses of 5,000 to 10,000 units per kg of fodder were found to be best. Continuous use was tested against periodical additions of it (every other day, every four days and every nine days). This showed that the antibiotic was effective only when used once every four days. Using it every other day, or every nine days, gave slightly less good results than using it every day. The dose of the antibiotic which gave the best result during the experiments, i.e. 20,000 units every three days, was then tested under commercial conditions. During two years of widely different weather conditions (1964 and 1965) the results were approximately the same. The average indices characterizing the expected efficiency of this preparation in conditions of pond farms should evidently be taken as: 9.5 percent for growth, 14 percent for stock increase and 10.5 percent for fodder saving.

The data obtained allow certain conclusions relating to the mechanism of the growth-stimulating effect of the antibiotic. The study of the weight composition of fish reared with the addition of terramycin to diversified fodder has shown that in the case of a more nutritious ration, containing natural food or animal fodder, the growth-stimulating effect tells first of all on small, undergrown specimens; the percentage of these decreases considerably and this accounts mainly for the increase in the mean weight of the stock. When a pure vegetable ration is used, the mean weight increases on account of an increase in the whole stock. Thus the antibiotic can evidently make up to some extent for the lack of animal protein in the ration. At the same time the study of the chemical composition of the muscles of the carp has shown that the antibiotic effect is concerned in the protein metabolism, the degree of the effect also depending on the quality of the diet. In the case of pure vegetable fodder and that containing 20 percent of animal food, the ratio of different forms of nitrogen in the muscles of the carp was such that the ratio residual : combined nitrogen with antibiotic was approximately 1.5 times lower than in control. This is evidence of a more intensive use of nitrogen. This is also confirmed by the higher content of combined nitrogen and raw protein in the muscles of the carp.

In the case of an increase in up to 35 percent animal food in the diet, no similar relationship was observed.

The data obtained make it possible to believe that the growth-stimulating effect of terramycin, if it is not conditioned by a change in nitrogen metabolism, is at least concerned with this aspect of development.

The study of the effect of growth-stimulating substances on the carp is continuing. On the basis of the experiments we recommend that growth-stimulating substances be added to feed mixtures and combined fodder for carp.

6 REFERENCES

Filatov, V.P., Tissue therapeutics treating with biogenous stimulants. Tashkent
1948

Korneeva, L.A., Application of fodder terramycin in feeding the carp with artificial
1963 fodder. Trudy vseross.nauchno-issled.Inst.prud.ryb.Khoz., 12

__________, The effect of fodder terramycin on the growth of the carp reared in
1965 nurseries. Trudy vseross.nauchno-issled.Inst.prud.ryb.Khoz., 13

Koval'skii, V.V. et al., Artificial change in cobaltic food chains and intensification of
1964 protein synthesis of fishes. Trudy vses.Akad.sel'.-khoz.Nauk im.Lenin, 7

Leonov, N.I., Antibiotics in live-stock raising and veterinary medicine. Moskva,
1963 Selkhozizdat

Sukhoverkhov, F.M., The effect of hydrolysis yeast on the growth of two-year-old carp.
1959 Ryb.Promyshl., (52)

Sukhoverkhov, F.M. and R.V. Krymova, The effect of cobaltic salts on the growth of the
1961 carp. Rybovod. i Rybolov., (1)

Sukhoverkhov, F.M., R.V, Krymova and V.G. Farberov, The effect of cobalt on the growth
1963 and haematological indices of the carp. Ryb.Khoz., (8)

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THE UTILIZATION OF FOOD BY TILAPIA MELANOPLEURA, DUM.

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Abstract

The utilization of protein and of cellulose by tilapia was determined by using the aquatic plants, Spirodela polyrrhiza and Elodea canadensis. The utilization of protein was between 42 and 57 percent and that of crude fibre between 43 and 68 percent.

L'UTILISATION DES ALIMENTS PAR LE TILAPIA MELANOPLEURA, DUM.

Résumé

La capacité d'assimilation des protéines et de la cellulose des tilapia a été déterminée au moyen d'expériences avec les plantes aquatiques Spirodela polyrrhiza et Elodea canadensis. L'assimilation des protéines varie entre 42 et 57 pour cent et celle des fibres brutes entre 43 et 68 pour cent.

EL APROVECHAMIENTO DEL ALIMENTO POR TILAPIA MELANOPLEURA, DUM.

Extracto

El aprovechamiento de proteínas y celulosa por la tilapia ha sido determinado utilizando las plantas acuáticas, Spirodela polyrrhiza y Elodea canadensis. El aprovechamiento de proteína fué del 42 al 57 por ciento, y el de fibra bruta entre el 43 y el 68 por ciento.

1 INTRODUCTION

Species of tilapia are widely cultivated in many countries of the world. Two of the more commonly used species are *Tilapia mossambica* and *T. melanopleura*. *T. mossambica* is omnivorous, whereas *T. melanopleura* feeds on plants. Examination of stomach contents has shown the nature of food consumed by them, but this information alone is not sufficient to designate the value of each food item. It is of great importance to know how the consumed food is being utilized. To solve such questions many experiments have been conducted (Chimits, 1957; Huet, 1960), but unfortunately we do not have evidence to show to what extent each food component is being digested and utilized by the fish.

The most important component of food is protein, which makes it possible to assess the nutritive value of foodstuffs to a certain degree by the measurement of its content of digestible nitrogen. Vegetable foodstuffs always consist to a certain degree of cellulose, and this component too is of importance for estimating nutritive values. Therefore in the present work the utilization of protein and of cellulose by *Tilapia* are the main points considered.

2 MATERIALS AND METHODS

The species chosen for the experiments was *Tilapia melanopleura* Dum. and each specimen was kept separately in a glass aquarium at 27°C. The water was well oxygenated. Based on previous experience of how much food the fish is able to eat, a weighed quantity of food was given to the fish. About one hour later the rejected food was removed and weighed, and the faeces were gathered for analysis. As the chemical composition of the food, mainly protein and cellulose, was known it was possible to tell the nutritive value of the consumed food from the quantity of these constituents in the faeces.

The analysis of crude protein was done by the procedure of Kjeldahl. The conversion of nitrogen to crude protein (in milligrams) was done by multiplying by the factor 6.25 (Mann, 1935). Crude fibre was determined by the well known Weender procedure.

3 RESULTS

Tilapia melanopleura feeds on plants. From the fry stage to a size of 3 to 5 cm it feeds on phytoplankton and unicellular algae, after which it prefers plants such as *Sparganium*, *Chara*, *Potamogeton*, etc. It eats artificial food only after having reached the size of 4 cm.

As it was not possible to conduct a quantitative feeding experiment with phytoplankton the study was limited to the higher plants. *Spirodela polyrrhiza* and *Elodea canadensis* were used for the experiments and their composition is given in Table I.

Table I

Composition of the aquatic plants used for feeding *Tilapia melanopleura*

	water %	protein %	fat %	crude fibre %
Spirodela polyrrhiza	96.7	0.6	0.008	1.03
Elodea canadensis	90.9	2.1	0.02	3.09

The fish digested its food rapidly because of the high water temperature (27°C). The last faeces appeared after 24 to 27 hours. The most abundant defaecation was noticed after 12 to 15 hours. When examining the faeces under a microscope one could still recognize the structure of the cells. The utilization of protein from both plant foods was between 42 and 57 percent (average 53 percent). The digestion of crude fibre, however, differed; the tilapia using 52-68 percent (average 64 percent) of the crude fibre from *Spirodela*, but only 43-55 percent (average 49 percent) of that from *Elodea* (Table II).

Table II

Utilization of food by Tilapia melanopleura

	protein %	crude fibre %
Spirodela polyrrhiza	42 - 55	52 - 68
Elodea canadensis	43 - 57	45 - 55

In previous experiments it had been found that carps and other cyprinids utilized from 80 to 95 percent of the nitrogenous material in their food (Mann, 1935; 1948). The digestion of lupin protein by carp was extremely high, 95 to 98 percent (Mann, 1938) compared with the 53 percent utilization by tilapia.

The utilization of crude fibre by carp from maize, lupin or rye varied from 20 to 90 percent according to the nature of the foodstuff.

4 REFERENCES

Chimits, P., 1957 The tilapias and their culture. A second review and bibliography. *FAO Fish. Bull.*, 10(1):1-24

Huet, M., 1960 Traité de pisciculture. Bruxelles, Ch. de Wyngaert. 369 p.

Mann, H., 1935 Untersuchungen über die Verdauung und Ausnutzung der Stickstoffsubstanz einiger Nährtiere durch verschiedene Fische. *Z.Fisch.*, 33:231-74

__________, 1938 Der Futterwert verschiedener Lupinenarten (Bitterlupine und Süsslupine). *Allg.Fisch.-Ztg.*, 64:3-7

__________, 1948 Uber die Rohfaser-Verdauung des Karpfens. *Arch.FischWiss.*, 1:1-11

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RELATIONSHIP BETWEEN RATE OF FEEDING, RATE OF GROWTH AND RATE OF CONVERSION IN FEEDING TRIALS WITH TWO SPECIES OF TILAPIA TILAPIA MOSSAMBICA PETERS AND TILAPIA NILOTICA LINNAEUS

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Abstract

An experiment was conducted to determine the relationship between feeding rate, growth rate and conversion in two species of tilapia. In *Tilapia mossambica* Peters growth rate increased four-fold when the feeding rate was increased from 1 to 2 percent. There was little increase in growth rate when the feeding rate was increased with increases in feeding rate from 1 to 4 percent. The best conversion rate was obtained at the 2 percent feeding rate with *T. mossambica* and at the 1 percent feeding rate with *T. nilotica*. Most economical rates of feeding were lower than the rates giving maximum growth.

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RAPPORTS ENTRE LA RATION ALIMENTAIRE, LE TAUX DE CROISSANCE ET LE TAUX DE CONVERSION CONSTATES AU COURS D'ESSAIS D'ALIMENTATION AVEC DEUX ESPECES DE TILAPIA, T. MOSSAMBICA PETERS ET TILAPIA NILOTICA LINNAEUS

Résumé

Des expériences ont été faites pour déterminer les rapports entre la ration alimentaire, le taux de croissance et le taux de conversion chez deux espèces de Tilapia. Avec *Tilapia mossambica* Peters, le taux de croissance quadruple lorsque la ration alimentaire est portée de 1 à 2 pour cent. Par contre, le taux de croissance n'augmente guère lorsque la ration passe à 3 et 4 pour cent. Le meilleur taux de conversion a été obtenu avec une ration alimentaire de 2 pour cent pour *T. mossambica* et une ration de 1 pour cent pour *T. nilotica*.

Les rations alimentaires les plus économiques sont inférieures aux rations donnant le maximum de croissance.

RELACION ENTRE LOS INDICES DE ALIMENTACION, CRECIMIENTO Y TRANSPORTE EN LOS ENSAYOS DE ALIMENTACION CON DOS ESPECIES DE TILAPIA, T. MOSSAMBICA PETERS Y TILAPIA NILOTICA LINNAEUS

Extracto

Se llevó a cabo un experimento para determinar la relación entre los índices de alimentación, de crecimiento y de conservación en dos especies de tilapia. En *Tilapia mossambica* Peters el ritmo de crecimiento aumentó al cuádruplo al elevarse la proporción de alimentación del 1 al 2%. Se registró poco incremento en el índice de crecimiento cuando la proporción de alimentación se aumentó con incrementos en la tasa de alimentación del 1 al 4 por ciento. El mejor índice de conversión o transformación de los alimentos se obtuvo a la tasa de alimentación del 2 por ciento con *T. mossambica* y a la del 1 por ciento con *T. nilotica*. Las tasas de alimentación más económica fueron más bajas que las tasas que daban el máximo crecimiento.

1 INTRODUCTION

The relationship between rate of feeding and rate of conversion is very important in fish culture. If fish are fed at too high a rate, much of the food is wasted, and, even though growth may be excellent the cost of production is excessive. Further, in some cases uneaten food decaying in the water may be detrimental to fish growth. If the feeding rate is too low, approaching the rate required for maintenance, growth is very slow, and the rate of conversion very high. In this case the amount of food fed is low, is largely wasted, and there is no growth.

The relationship between feeding rate and conversion rate is dependent on the species of fish, size of fish, quality of food and water temperature. The research reported here was conducted to determine the relationship between rate of feeding, rate of growth and conversion in feeding trials involving *Tilapia mossambica* Peters (Java tilapia) and *T. nilotica* Linnaeus (Nile tilapia).

2 EXPERIMENTAL PROCEDURE

Tilapia being wintered in troughs in the Fisheries Laboratory were used in these experiments. The 16 troughs of tilapia, eight troughs of Java tilapia and eight troughs of Nile tilapia were fed a percentage (1, 2, 3 or 4 percent) of their body weight each day for six days per week for four weeks (11 March 1959 to 7 April 1959). Each feeding rate was replicated in two troughs for each species. The amount to be fed each day was calculated on the basis of total weight of fish in each trough at the beginning of the experimental period. At the end of two weeks the fish in each trough were weighed, and the amount fed was adjusted to the gain in weight of the fish during that 14-day period.

Troughs with Java tilapia contained an average of 9.44 kg of fish at the beginning of the experiment. Troughs with Nile tilapia contained an average of 14.74 kg of fish.

The diet used in these experiments consisted of 80 percent Auburn No.2 meal (35 percent peanut meal, 35 percent soybean meal, 15 percent fish meal, 15 percent distiller's dry solubles) and 20 percent finely ground beef liver. The diet was prepared by mixing liver with water to form a heavy slush. This slush was then added to the meal and mixed until the resulting product was about the consistency of wet sawdust. It was found necessary to add the liver to water before adding it to the meal. Finely ground liver added directly to the meal resulted in a product that could not be evenly mixed.

The diet was mixed each morning and weighed into plastic cups. The fish were fed a day's ration in two to four daily portions. The fish receiving 1 percent of their body weight per day were usually fed twice. Fish receiving 4 percent were fed four or even five times per day. This was necessary because of the relatively small stomach capacity of the tilapia. If too much feed was added to the trough at one time, the fish quickly became gorged, leaving feed on the bottom of the trough. Utilization of feed on the trough bottom was usually poor in troughs being fed at the higher rates.

The troughs were partially cleaned each day. Troughs in which fish were being fed at lower rates (1 or 2 percent) could be cleaned by washing the space behind the retaining board. Apparently because of activity of the fish, the small amount of waste feed and faeces present in these troughs was washed under the board. In troughs in which fish were being fed at the 3 or 4 percent rate, the sweeping action of the fish was not sufficient to keep the troughs clean. These troughs were cleaned either by draining to a low level and sweeping out the wastes, or by using a siphon hose to remove the collected faeces and waste feed. Water was added to the troughs continuously at a rate sufficient to provide about one change of water per hour.

3 RESULTS OF FEEDING TRIALS WITH JAVA TILAPIA

The gains in weight of fish receiving the different levels of feeding are expressed as a percentage of the initial weight of fish. These are termed growth rate throughout this paper. The growth rate data resulting from the feeding trials with Java tilapia are as follows:

Percent fed	Growth rate	Conversion
1	5.8	4.1
2	19.9	2.5
3	20.6	3.6
4	18.0	5.6

Each value represents the average growth rate of the two troughs of fish receiving the same feeding rate.

The foregoing data indicate that an increase in feeding rate from 1 to 2 percent was sufficient to provide enough feed to raise the growth rate of the fish from just above maintenance to almost maximum; increase to 3 percent in the feeding rate resulted in only a small increase in growth rate. There is some suggestion in these data that feeding 4 percent per day brought about a reduction in growth when compared with feeding rates of 2 and 3 percent. This is probably a result of excessive accumulation of waste products of metabolism and some unused feed in troughs fed at this higher rate.

The table presents data obtained on the relationship between feeding rate and conversion rate in feeding trials with the Java tilapia. Each value represents the average conversion rate (grams of feed required to produce a gram of fish) for two troughs of fish receiving the same rate of feeding. The data on the conversion rates presented in the table indicate that at the lowest rate of feeding the amount of feed given was just enough for maintenance with very little left for growth. In this situation the conversion rate was high. At the highest rate of feeding more feed was presented to the fish than could be eaten or utilized. In this case the conversion of feed into fish was also poor, and a high conversion rate was obtained.

Since both low and high feeding rates produced unfavourable conversion rates, it is apparent that maximum efficiency for converting feed into fish flesh is obtained at some intermediate rate of feeding. These data suggest that the optimum feeding rate for Java tilapia under conditions of this experiment was a little above 2 percent of body weight per day.

4 RESULTS OF FEEDING TRIALS WITH NILE TILAPIA

Growth rate data resulting from the feeding trials with Nile tilapia are presented in the following table. Each value represents the average growth rate of two troughs of fish receiving the same rate of feeding.

Percent fed	Growth rate	Conversion
1	8.9	2.8
2	12.3	4.0
3	13.8	5.4
4	16.1	6.0

These data indicate that the growth rate of Nile tilapia increased slightly with increases in the amount of feed presented to the fish at all levels of feeding. These results are contrary to those obtained in the feeding trials with the Java tilapia. With that species increasing the feeding rate above 2 percent did not result in increasing the growth rate. The cause of the difference in response in growth rate between the two species is not known.

The above table also contains data obtained on the relationship between feeding rate and conversion rate in feeding trials with the Nile tilapia. Each value represents the average conversion rate for two troughs of fish. Conversion rates obtained with Nile tilapia increased steadily with increases in the feeding rate. These data suggest that the feeding rate producing the most efficient conversion with the feed used may be below 1 percent per day. These results are different from those obtained with Java tilapia. With the Java tilapia the feeding rate for the most efficient conversion was about 2 percent. This difference probably represents the effect that quality, formulation and physical consistency of feed had on feed intake and utilization in different species of fish.

The results obtained in the feeding trials with both species indicate that maximum growth rate does not necessarily accompany maximum efficiency of feed utilization. With both species increases in growth rate were obtained above feeding rates giving the best conversion rates. This is probably a result of the mechanics of feeding the fish. If the fish could be provided with exactly the amount of feed for maximum growth without any waste, maximum efficiency and maximum rate of growth would probably be obtained at the same feeding rate. However, when the fish are fed the entire ration for the day in two or three portions some waste is probably inevitable. This wastage is increased as the rate of feeding is increased.

5 CONCLUSIONS

A study of the relationship between rate of feeding, rate of growth, and rate of conversion by Java tilapia and Nile tilapia yields the following conclusions: (i) With the Java tilapia growth rate was increased four-fold by increasing the feeding rate from approximately 1 to 2 percent. Further increases in the feeding rate resulted in only a slight increase in growth rate. There was some indication that the highest rate of feeding (4 percent) resulted in reduced growth. Growth rates of Nile tilapia increased slightly with all increases in the feeding rate. (ii) With the Java tilapia the best conversion rate was obtained at the 2 percent feeding rate. Feeding rates above and below resulted in poorer conversions. With the Nile tilapia, the best conversion was obtained at the 1 percent feeding rate. Conversion rates increased at feeding rates above 1 percent. (iii) With both species optimum conversion rates were obtained at feeding rates lower than those providing maximum growth rates. This resulted probably from the mechanics of feeding or from the frequency of feeding.

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III/E-10

ESTIMATION OF STANDING CROPS AND RATES OF FEEDING FISH IN PONDS

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Abstract

Rate of daily feeding is calculated either as a percentage of the total weight of the standing crop or on the basis of the daily increase in total weight of the standing crop. Both methods are subject to two sources of error. The first is the possible error in estimating the average weight of the population and the second is the error in estimating the number of individuals in a population at any one time, on the basis of seining samples.

Estimates of standing crops may be made from the total amount of daily feed added up to any one point from the equation:

$$W = IR^N, \text{ where}$$

I = initial weight of fish,

R = the rate of change in weight during interval T, and

N = number of intervals "T" at which the daily feeding is readjusted.

For estimation of the rate of change in weight "R", it is necessary to know the pond conversion value "S" for the feed used at the rate it is being fed:

$$R_T = \frac{1 + DP}{S}, \text{ where}$$

D = number of days feed is added during interval T,

T = intervals at which feeding rate is readjusted,

P = daily feeding rates from 0.02 to 0.05, (2 percent to 5 percent of body weight),

S = pond conversion value at P and T for a particular feed and for a particular species of fish.

III/E-10

ESTIMATION PONDERALE DU STOCK ET DE LA RATION ALIMENTAIRE DES POISSONS EN ETANG

Résumé

La quantité d'aliments fournie journellement est calculée soit en pourcentage du poids total du stock présent, soit sur la base de l'accroissement journalier du poids total de ce stock. Les deux méthodes peuvent être entachées d'erreurs au départ: erreur dans l'estimation numérique du stock à un moment donné.

Une estimation pondérale du stock peut être faite à partir du poids total de la ration alimentaire quotidienne sommée jusqu'au moment considéré à l'aide de l'équation suivante:

$$W = IR^N \quad \text{où}$$

I = poids initial du poisson
R = le taux d'accroissement en poids au cours de l'intervalle T, et
N = le nombre d'intervalles "T" où la ration quotidienne a été modifiée

Pour estimer le taux d'accroissement de poids "R", il faut connaître le taux de conversion "S" applicable à l'étang en fonction des aliments fournis et de la quantité distribuée:

$$R_T = \frac{1 + DP}{S} \quad \text{où}$$

D = le nombre de jours durant lesquels une ration alimentaire est fournie pendant l'intervalle T
T = les intervalles auxquels la ration alimentaire est modifiée
P = le taux d'alimentation quotidien allant de 0,02 à 0,05 (2 à 5 pour cent du poids corporel
S = le taux de conversion de l'étang en fonction de P et T, pour un aliment déterminé et une espèce donnée de poisson

ESTIMACION DE LOS RECURSOS POTENCIALES EXISTENTES Y TASAS DE ALIMENTACION DE LOS PECES EN LOS ESTANQUES

Extracto

La proporción de alimentación diaria se calcula, sea como porcentaje del peso total de los efectivos existentes de la población, sea sobre la base del incremento diario del peso total de dichos efectivos. Ambos métodos están sujetos a dos causas de error. El primero es el posible error en la estimación del peso medio de la población, y el segundo es el que procede de la estimación del número de individuos en una población en un momento cualquiera sobre la base de muestras obtenidas mediante redes de cerco. La estimación del efectivo en organismos puede realizarse partiendo de la cantidad total de alimento añadida en cualquier punto, de la ecuación:

$$W = IR^N, \text{ en la que}$$

I = peso inicial del pez,
R = cambio en peso durante el intervalo T, y
N = número de intervalos "T" a los cuales ha sido reajustada la alimentación diaria,

Para la estimación de la tasa de cambio en peso "R", es necesario conocer el valor "S" de conversión en el estanque para el alimento utilizado en la proporción en que se suministró:

$$R_T = \frac{1 + DP}{S}, \text{ en la que}$$

D = número de días en que se ha añadido alimentos durante el intervalo T,
T = intervalos a los que se ha reajustado la proporción de alimentación,
P = tasas diarias de alimentación de 0,02 a 0,05 (2% a 5%) del peso corporal,
S = valor de conversión del estanque para P y T y para un alimento determinado y una especie determinada de pez.

1 SOURCES OF ERRORS IN COMPUTATION OF STANDING CROPS AND RATES OF FEEDING

The successful fish culturist must supply feed to his fish at daily rates that allow efficient food utilization. In American and European fish cultures, amounts to be fed daily are calculated upon the basis of a certain percentage of the body weight of all fish in the pond (the standing crop). The percentage rate used varies with temperature and size of the fish being fed; the amount fed is readjusted weekly, bi-weekly, or monthly as the crop increases in total weight and average size.

In Israel, Tal (1956) recommended bi-weekly seining to determine the average daily growth of the common carp (Cyprinus carpio). The average daily increase during the past two-week period expressed as gain in kilos per hectare per day is then multiplied by a factor to give the amount of feed to be given the fish daily during the next two-week period. The factors recommended increase with increasing average size of the carp.

Both methods rely upon estimates of average size of fish made from seining samples and the results are multiplied by the number of fish estimated to be present per hectare, in one case to estimate the weight of the standing crop and in the other to estimate gain per hectare per day.

The estimates are thus open to two main sources of error. First, the average weight of fish taken in the seine may not represent the true average weight within the population at that time. In experiments at Auburn, it was found necessary with the channel catfish (Ictalurus punctatus) to weigh a sample of not less than 100 fish from ponds ranging from 0.5 to 10 ha to obtain a relatively accurate average. Despite such care, average weights of fish taken by seining have occasionally varied as much as eight to 19 percent from the average found by draining and weighing all fish a few days later. With Tilapia mossambica or T. aurea, samples of 300 or more fish were necessary for accurate estimates. Seining samples taken at times of day when fish were not being fed often appeared to underestimate the average size. It seemed probable that smaller fish remain in the shallow water and were thus more vulnerable to seining. Seining shortly after feeding often gives abnormally high weights for larger fish due to their habit of cramming their stomachs with more than their share of feed. Corrections can be made for this by using average weights of fish of the same lengths in the calculations.

The second source of error in estimating feed required is that the fish culturist seldom knows accurately the number of fish per hectare. He usually knows the number stocked and may know the average mortality at draining. He thus may use the number stocked or the average survival in his calculations. Use of either often leads to serious errors in calculations of the feed to be given daily. With the scaled variety of common carp, at this Station survivals normally varied from 97 to 100 percent per year and here use of the number stocked caused no serious error provided the pond was protected to prevent loss of carp durin heavy outflows of water. The mirror variety of common carp has given survivals from 80 to 90 percent per year, whereas tilapias had survivals from 65 to 90 percent. In these cases estimates of the fish present may be quite inaccurate.

2 USE OF AMOUNT OF FEED SUPPLIED FOR ESTIMATES OF STANDING CROPS

2.1 Calculation of pond conversion value "S"

The need for additional and better methods of estimating the standing crop of fish is quite evident. Where a standard feed is used and where conversion rates for this feed are known for a particular species and for various rates of feeding, it appeared that this information could be used to give an estimate of standing crop by adding the expected gain from the feed to the weight of fish stocked. Since the feed and wastes directly or indirectly from feeding will produce additional fish-food organisms, it is better to use the pond conversion value (S) which is calculated: $S = \frac{\text{kg feed added}}{\text{net kg fish produced}}$

2.2 Sizes of tilapia and efficient rates of feeding

For Java tilapia, *Tilapia mossambica*, Nile tilapia, *T. aurea*, and Congo tilapia, *T. melanopleura*, with Auburn No. 2 pelleted feed[1] during periods when the water temperatures remained above 22°C (70°F), "S" conversions varied from 0.7 to 1.2 with an average of 1.0 when fed at the rate given below for various sizes of fish:

Average total length		Rate daily
cm	in	Percent of body weight
2.4 - 12.0	1 - 5	5
12.0 - 24.0	5 -10	3

2.3 Sizes of catfish and efficient rates of feeding

In experiments with both white catfish (*Ictalurus catus*) and channel catfish, "S" conversion values for the Auburn No. 2 pelleted feed, when water temperatures were above 16°C, varied from 1.5 to 2.0 with an average of 1.7 when the daily feeding rate for various sizes of fish were:

Average total length		Daily rate of feeding
cm	in	Percent of body weight
2.4 - 12	1 - 5	5
12.0 - 15.6	5 - 6.5	4
15.6 - 24.0	6.5 - 10	3
24.0 - 28.5	10 - 12	2.5
31.2 plus	13 plus	1.5

2.3.1 Variations in "S" values

Results indicated that use of a standard pond conversion value of 1.7 for both channel catfish and white catfish estimated final production satisfactorily, but underestimated the standing crops during spring and summer. This evidently was because natural fish-food organisms furnished a material part of the feed until a weight of approximately 1,000 kilos fish per hectare was reached. Examination of the data indicated that natural feeds were causing growth during summer period of approximately 2 kg/ha of fish per day. In effect, the "S" pond conversion then becomes a constantly increasing value during this period of growth. The average calculated "S" values for gradually increasing total cumulative feed, using average seining values for standing crops were as follows:

Cumulative feed added, kg	Conversion S
100	0.5
200	0.7
400	0.8
800	1.1
1000	1.2
1200	1.3
1500	1.5
1700	1.7

---

[1] Pelleted dry feed containing 46 percent protein, 25 percent carbohydrates and 5 percent fat (Prather, 1958).

2.3.2. Estimation of the standing crop from feeding records, seining and from draining

Following are comparisons of standing crop estimates in kg/ha made from seining records, by dividing total cumulative feed by the appropriate S conversion, and that found upon draining.

By seining	From feed	Upon draining
235	253	
433	578	
692	690	
-	1170	1303
183	249	
366	378	
501	708	
-	1204	1185
231	370	
363	560	
783	892	
1495	1251	1255
251	320	
531	480	
847	892	
1288	1252	1193
876	835	
764	1020	
1995	1761	
-	3165	3544

While disagreements in estimates of standing crop occurred, that calculated from feed supplied appeared as accurate as that from seining records.

In other experiments in these ponds without feeding or fertilization, the standing crop has averaged 97 kg/ha at the end of 210 days. If this correction is applied, the final S conversion would be changed by approximately 0.1 - from 1.7 to 1.8. The same correction cannot be applied to the S conversion for standing crops from 200 to 700 kg and would not help in estimating these standing crops.

2.4 Equation for estimation of standing crop from feed supplied

From these data it would appear that relatively reliable estimates of the standing crop or yield may be made from the equation:

(1) Standing crop = I plus $\frac{F}{"S"}$

where I = initial weight of fish stocked

F = weight of feed added

S = pond conversion value for cumulative amount of feed added and for the species of fish stocked.

For example channel catfish, where I = 50 kg; F = 2210 kg Auburn No. 2 pelleted feed; and S = 1.7, with the range 1.5 - 2.0.

$$\text{Standing crop} = 50 \text{ plus } \frac{2210}{1.7} = 1350 \text{ kg}$$

$$\text{but varying from } 50 \text{ plus } \frac{2210}{1.5} = 1523 \text{ kg}$$

$$\text{to } 50 \text{ plus } \frac{2210}{2.0} = 1155 \text{ kg}$$

Calculations of standing crops from the feed should be useful in checking the accuracy of estimates from seining. It is evident that both are subject to certain inaccuracies, but from different sources.

2.5 Equations relating to expected weight of fish

From the foregoing results, it also appeared possible to devise equations relating feed supplied to the standing crop of fish to be expected after a certain period of feeding, as follows:

(2) $R_T = 1 + \frac{DP}{S}$ = Rate of change in weight during interval T

when D = number of days on which feed is added during interval T;

T = equal intervals at which feeding rate is readjusted (e.g. 1-week, 2-week, and 4-week intervals.);

P = daily feeding rates from 0.02 to 0.05 (2 percent to 5 percent rates); and

S = pond conversion values at P and T for a particular feed and for a particular species of fish.

Example: Where T = 4 weeks, D = 24 when feeding is 6 days weekly, then, for the channel catfish where P = 0.03 and S = 1.6, $R = 1.0 + \frac{(24)(0.03)}{1.6} = 1.45$

The general forms of the equations are:

(3) $W = I\left(1.0 \text{ plus } \frac{DP}{S}\right)^N = IR^N$; or $\log W = \log I \text{ plus } N \log R$

where W = total weight of the standing crop at end of N intervals of feeding;

N = number of T intervals during which fish have been fed at rate "P";

I = initial weight of fish, then

Number of "T" intervals of feeding required to reach a certain weight are:

(4) $N = \frac{\log W - \log I}{\log R}$, and

Initial weight required to reach a specified total weight is:

(5) $\log I = \log W - N \log R$.

The above equations are useful in planning methods of management and in understanding the factors affecting production.

2.5.1 Limits of feeding within which the equations apply.

Range of use is limited by the maximum safe rates of feeding/hectare/day, which, when using Auburn No. 2 pelleted feed with the following species are:

Channel catfish - - - - 39 kg; 34 kg in mid-summer

White catfish - - - - - 39 kg; 34 kg in mid-summer

Java and Nile tilapia - 55 kg

Congo tilapia - - - - - 38 kg.

In addition, feeding must be at water temperatures above 16°C.

Since the above are limitations in the usefulness of equations (3), (4), and (5) it is evident that for channel catfish fed at the three percent rate, we can calculate as follows the maximum W for which the equation holds.

$$3\% = 39 \text{ kg}$$

$$100\% = \frac{100}{3} \times 39 = 1{,}300 \text{ kg/ha}$$

2.5.2 Examples of calculations

Where 40 kg of channel catfish are stocked and fed Auburn No. 2 pellets six days weekly, with feeding readjustments to three percent of weight of standing crop weekly for a period of 30 weeks, then

$I = 40$, $D = 6$, $T = 1$ week, $N = 30$ T., $P = 0.03$, and $S = 1.7$;

and, $R = 1.0 + \frac{(6)\ (0.03)}{1.7} = 1.106$, Equation (2);

then, $\log W = \log 40 + 30 \log 1.106$, Equation (3);

$\log W = 2.91486$

$W = 821$ kg

If W exceeds 1,300 kg/ha, it is necessary first to calculate the weeks of feeding required to reach 1,300 kg using equation (4),

$$N = \frac{\log W - \log I}{\log R} = \frac{\log 1{,}300 - \log 40}{\log 1.106} = 35 \text{ "T" intervals} - 35 \text{ weeks}$$

If we are attempting to produce 2,000 kg of catfish, the remainder of the time we cannot feed more than 39 kg of feed per day. If we feed six days per week, the increase in weight of catfish per week is:

$$\frac{39 \times 6}{1.7} = 137 \text{ kg}$$

Then the added weeks needed to increase from 1,300 kg to 2,000 kg $= \frac{700}{137} = 5.1$ weeks.

The total time required is then $35 + 5.1 = 40.1$ weeks. If we wish to reduce this time, we must start with a higher weight of fish: that is, either more fish of the same average size, or the same numbers of fish of larger size.

2.5.3 Calculation of feed required for maintenance

If we use a much larger initial weight of fish, another factor must be considered. The feeding rate with Auburn No. 2 pellets required to maintain weight of fish without growth is approximately 0.5 percent of their weight per day six days per week. If we start with 50 kg of fish in one case and 200 kg in another and continue feeding (six days weekly) for a 30-week period, the feed required for maintenance of this original weight for the former is:

$$50 \times 0.005 \times 30 \times 6 = 45 \text{ kg},$$

and for the latter:

$$200 \times 0.005 \times 30 \times 6 = 180 \text{ kg}.$$

The daily difference in maintenance requirements is first met and only the remainder of the feed is available for growth.

Where small fish (less than 15 cm) are grown to large size, usually no correction is needed in the equations given. However, a correction is necessary when high weights or large fish are fed for a short period of time. Equation (1) then becomes:

$$\text{Standing crop} = I \text{ plus } \frac{F-M}{S}, \text{ when}$$

I = initial weight of fish stocked,

F = total weight of feed supplied, and

M = I x 0.5% x number of days fish were fed.

In equation (2) the correction can be made by subtracting 0.5 percent from the percentage of daily feeding, P.

3 REFERENCES

Tal, S., 1956 A criticism of the methods of calculation of carp feeding. Bamidgeh, 8(3):44-51

Prather, E. E., 1958 Further experiments on feeds for fathead minnows. Proc.Conf.stheast.Ass. Game Commrs., 12:176-8

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